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Study of Leaf Area as Functions of Age and Temperature in Rice (*Oryza sativa* L.)[1]

Chwen-Ming Yang[2] and James L. Heilman[3]

Abstract : Correlations between the measured and the estimated leaf areas of rice plants as functions of age and temperature were studied. The results showed that as the plant advances area can be estimated from leaf dimensions in a controlled-environment. When temperature treatment is imposed, causes that alter leaf length/width ratio may change the measured values. Different sets of regression analysis, therefore, may be needed for leaf area estimation when temperature stress occurs.

Key Words : Leaf area, Age, Temperature, Rice, *Oryza sativa* L., Leaf dimensions

Introduction

Leaf area is one of the observed characters of plant growth in favor of quantitative description. When the productivity of crops or an ecosystem in nature is concerned, the performance of leaf area per unit of ground area, namely, leaf area index (LAI), is frequently used as a measure of this expression (Beadle, 1985 ; Watson, 1947). However, the destructive nature of sampling technique in growth analysis makes it difficult for future inquiry and study. The non-destructive approach for leaf area measurement, therefore, has an important advantage since the same plants can be repeatedly sampled and the variability of individuals and populations may be eliminated (Beadle, 1985).

By this approach, the charactersitics related to leaf area, i.e., the length and width of leaves, must be measured and the relationship between length and width and leaf area must be established from harvested samples. The gain and loss of leaf area can then be derived from regression equations relating leaf area to the characteristics measured. Accurate measurements of leaf dimensions are essential to avoid unnecessary variation.

In this study, the objective is focused on the linear regressions of the measured and the estimated leaf areas. Such correlations as functions of age and temperature effects are also investigated. The information is particularly useful for studies of parameters related to leaf production in controlled environments and growth analysis (Beadle, 1985 ; Hunt, 1982).

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1. Contribution No. 1533 from Taiwan Agricultural Research Institute.
2. Agronomist, Department of Agronomy, TARI, Wufeng 41301 Taichung, Taiwan, ROC.
3. Associate professor, Department of Soil & Crop Sciences, Texas A&M University, College Station, Texas 77843, USA.

Materials and Methods

Plants of rice variety LEMONT (Bollich et al., 1973, 1984, and 1985) were grown in opaque plastic containers (.25 m diameter, .20 m height), three plants per pot with even space, filled with fritted clay and irrigated with nutrient solutions. The composition of nutrient solution and the schedule of watering are listed in Tables 1 and 2, respectively. Physical properties of fritted clay has been tested by van Bavel et al. (1978). They were grown as groups in a controlled-environmnent chamber circulated with ambient air (day /night temperature 30°C/20°C ; relative humidty 50−70%/90−100% ; CO_2 concentration 330—430 ppm). The daylength was 12 hours with PPFD about 650 μmole m^{-2} s^{-1}. When reaching the appropriate test stages (Table 3), some plants were moved to an assimilation cabinet for 8-day temperature treatments. At the end of treatments, half of the plants were sacrificed and the rest were grown in the growth chamber until harvest.

Table 1. The composition of nutrient solution (full strength, X).

Element	Concentration (mg l^{-1})	Element	Concentration (mg l^{-1})
Nitrogen (N)	320	Iron (Fe)	3.0
Phosphorus (P)	210	Sodium (Na)	2.3
Potassium (K)	320	Manganese (Mn)	1.0
Calcium (Ca)	280	Copper (Cu)	0.6
Magnesium (Mg)	40	Zinc (Zn)	0.4
Sulfur (S)	180	Boron (B)	1.0
Cloride (Cl)	3.5	Molybdenum (Mo)	0.1

The pH value is adjusted to 6.8 with 1 N sodium hydroxide (NaOH) solution.

Table 2. Schedule of watering nutrient solutions.

Stage	Strength
Seeding to Transplanting	1/32 X
Transplanting to Leaf 3 stage	1/16 X
Leaf 4 stage to Leaf 5 stage	1/8 X
Leaf 6 stage to Heading	1/4 X
Heading to R-2 stsge	1/8 X
R-3 stage to Harvest	1/16 X

Table 3. The design of temperature treatments.

Symbol	Treatment	Description
V25	25 C at vegetative stage*	Collected after treatment
VH25	25 C at vegetative stage	Collected at harvest
V35	35 C at vegetative stage	Collected after treatment
VH35	35 C at vegetative stage	Collected at harvest
G25	25 C at grain-filling stage **	Collected after treatment
GH25	25 C at grain-filling stage	Collected at harvest
G35	35 C at grain-filling stage	Collected after treatment
GH35	35 C at grain-filling stage	Collected at harvest

*Leaf 7 stage
**From the 8th day to the 15th day from heading.

Every 7 days and 3 days, the pots were flushed with distilled water to avoid salt accumulation during the vegetative and the reproductive stages, respectively. They were rotated periodically to ensure uniformity within the chamber.

The assimilation cabinet was set for a photoperiod of 12 hours and a constant day/night temperature and absolute humidity. The average value of PPFD at the top of the cabinet was about 1300 μmole m^{-2} m^{-1}.

The area of leaf was determined by area meter (LI-3000, LI-COR, Inc., Nebraska, USA), while the estimated leaf area was the product of leaf length and leaf width. Leaf dimensions were taken before plants were harvested. The relations between the measured and the estimated values were analyzed by the linear regressions. Of the whole plant, only dead tissues were excluded from the measurements.

The leaf stage (plant age) was assessed by the emergence of the primary leaf on the main culm (Yoshida, 1981). When the 8th primary leaf emerges from the main culm, the plant is said to be at Leaf 7 stage ; the Heading stage is from the first day to the 7th day from heading, the R-1 stage is from the 8th to the 14th day from heading, and so on.

Results and Discussion

Age Effect

The linear regressions were calculated between stages from Leaf 5 stage until the harvest. The leaf area estimated from dimensions against the measured values are plotted in Fig. 1. The results showed that as the plant age advanced the relationship between the estimated and the measured leaf areas remain unchanged, which implies that a constant proportion of leaf length/leaf width may be maintained under the experimental conditions. Changes of leaf area can therefore be estimated from leaf dimensions from Leaf 5 stage throughout the life cycle of rice plant in a controlled environment.

Temperature Effect

When Figs. 2 and 3 were compared, the results indicated that a short term (8 days) temperature treatment at the vegetative stage may affect leaf dimensions, the lenght/width ratios, to some extent. But this effect may not be distinguished between treatments

at harvest, if the treated plants are allowed to grow to maturity. Also, such treatments may somewhat alter the uniformity of the length/width ratio within the same treatment as the plants continually develop (Figs. 4 and 5). A prallel fashion was shown from young plants to matured plants. Different sets of regression analysis, thus, may be needed for leaf area estimation when temperature stress is imposed. The relationship determined for the plant in the early age may not be used for the matured one, and vice versa.

In addition, short term temperature variations at grain-filling stage will also influence leaf dimensions (Figs. 6 and 7). It suggests that the tillering capability and the emergence rate of leaf, and hence leaf age and leaf number, are affected by temperature treatments. As a result, leaf area may not be estimated from data obtained in previous conditions but rather from new environment. Further, as shown in Figs. 8 and 9, the ratios of length/width of newly produced leaves may also be altered within the same treatment as the plant ages.

The study reveals that under a controlled environment leaf area may be estimated from the calculation of leaf dimensions in rice plants. However, when the growth conditions are changed either at vegetative or grain-filling stage, due to temperature or other factors, different regression analyses should be made to excldue the variation from plant growth and development. Such enviromnental fluctuations are often the case in the field that may significantly interfere plant growth. Accordingly, the measured rater than the estsimated leaf area should be used.

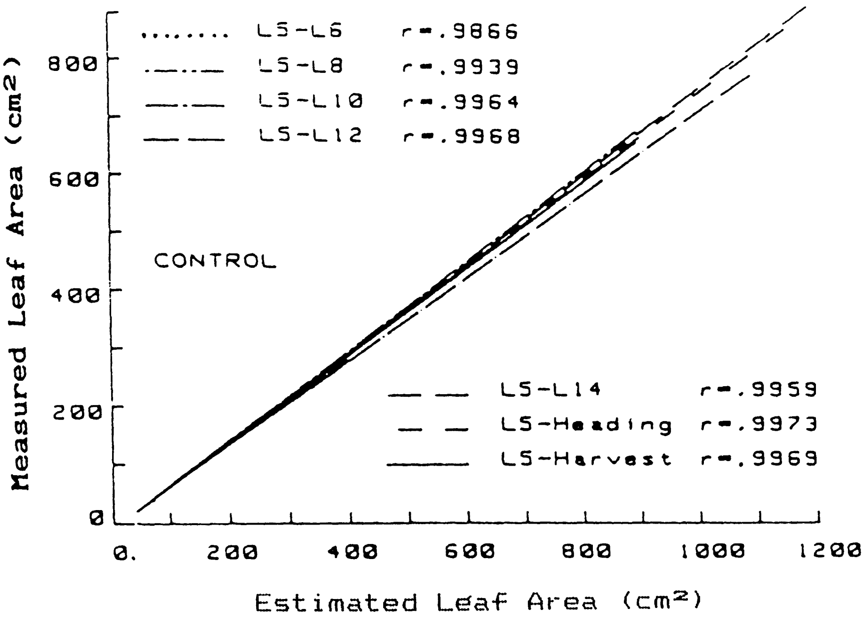

Fig 1. Regression analysis of the correlation between the estimated and the measured leaf areas as a function of leaf stage (plant age) under controlled environment conditions. L5-L6 represents the areas of leaf that were measured/estimated from Leaf 5 stage to Leaf 6 stage, and so on. The values of r are the correlation coefficients.

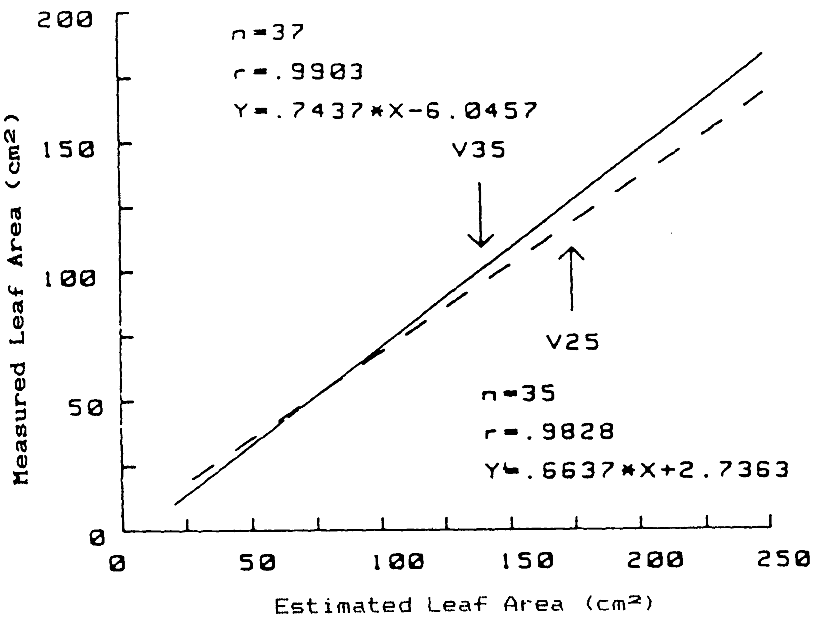

Fig 2. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the vegetative stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. V25 and V35 were the 25 C and 35 C treatments at the Leaf 7 stage, respectively.

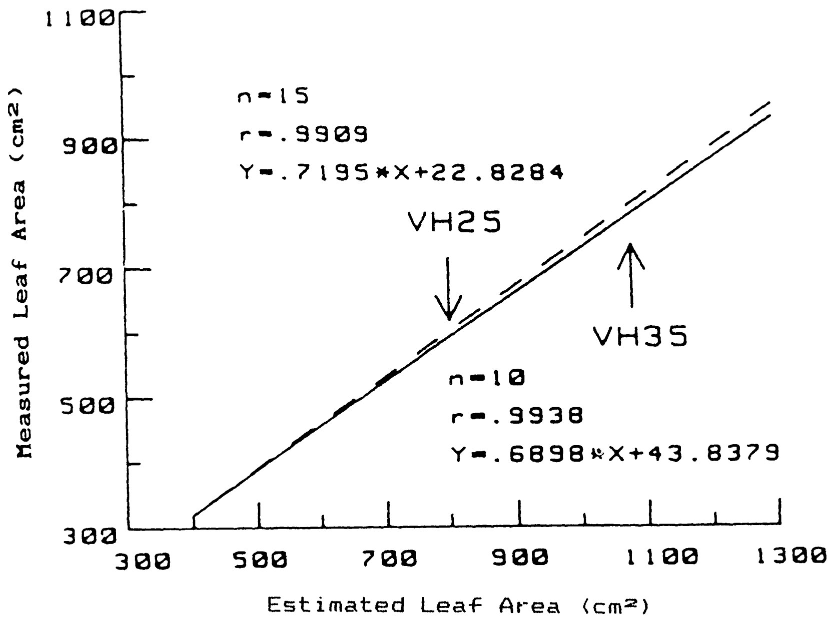

Fig 3. Temperature effects on the linear regressions of the estimated leaf areas to the measured values at harvest. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. VH25 and VH35 were the 25 C and 35 C treatments at the Leaf 7 stage and collected at harvest, respectively.

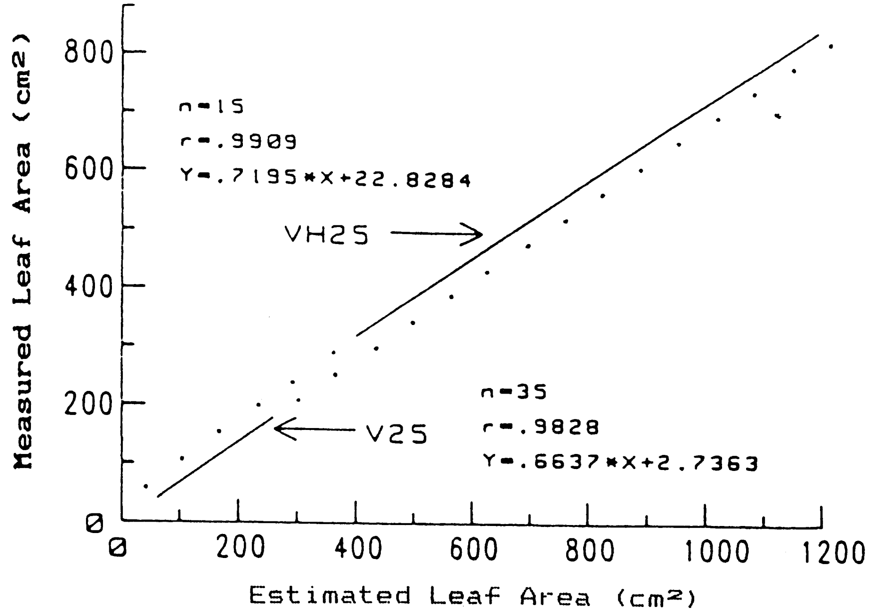

Fig 4. Age affects on the linear regressions of the estimated areas to the measured values of the 25 C-treated plants. Plants of V25 were harvested after treatment, while plants of VH25 were harvested after grown to maturity.

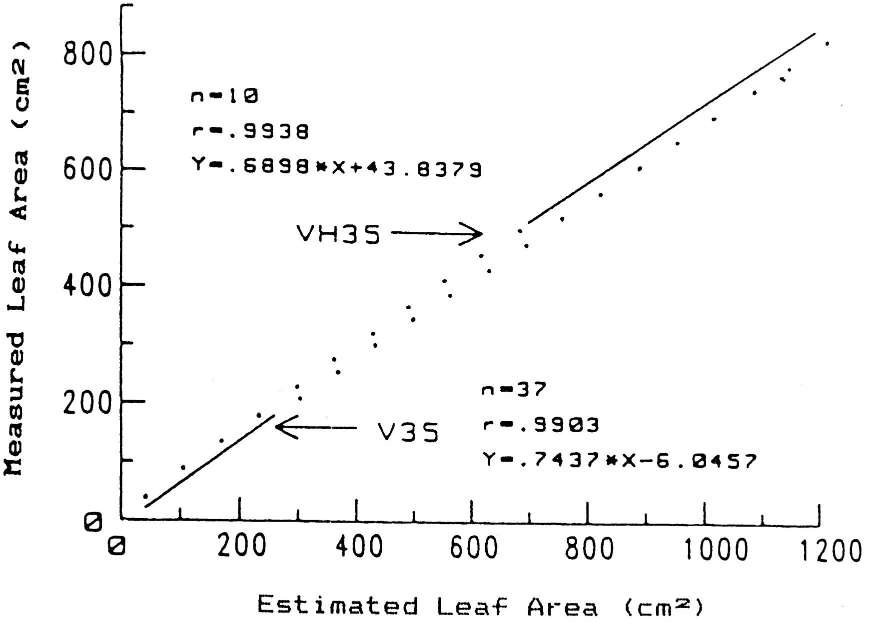

Fig 5. Age affects on the linear regressions of the estimated areas to the measured values of the 35 C-treated plants. Plants of V35 were harvested after treatment, while plants of VH35 were harvested after grown to maturity.

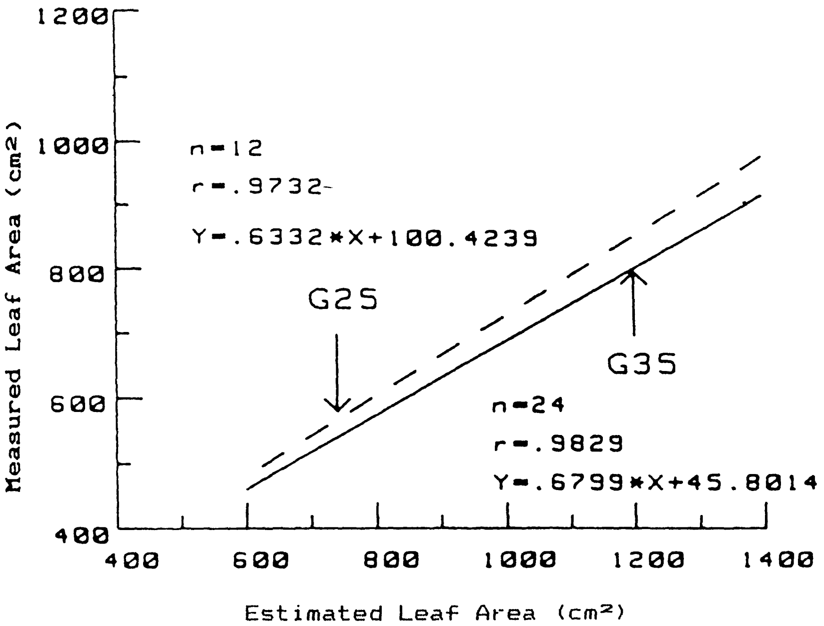

Fig 6. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the grain-filling stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. G25 and G35 were the 25 C and 35 C treatments at the R-1 stage (8th to the 15th day from heading), respectively.

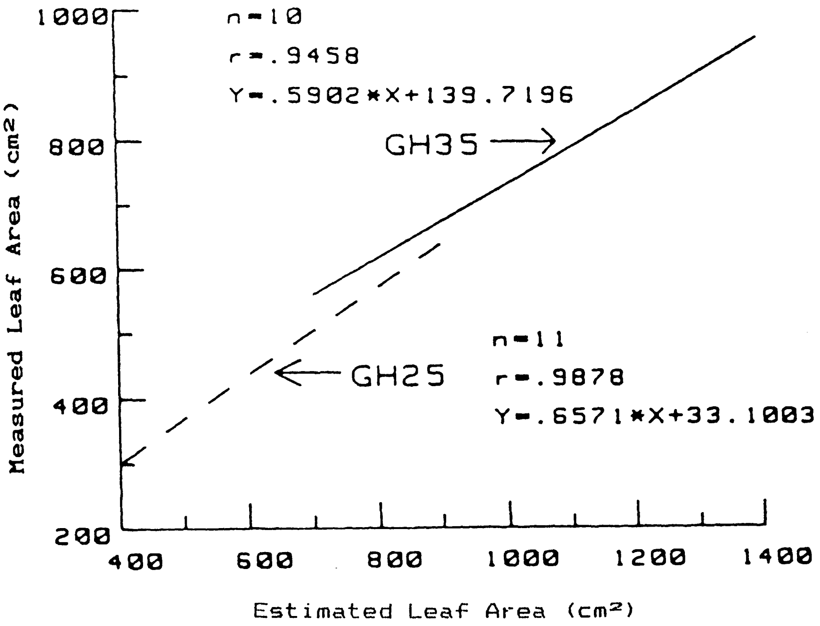

Fig 7. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the grain-filling stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. GH25 and GH35 were the 25 C and 35 C treatments at the R-1 stage (8th to the 15th day from heading) and collected at harvest, respectively.

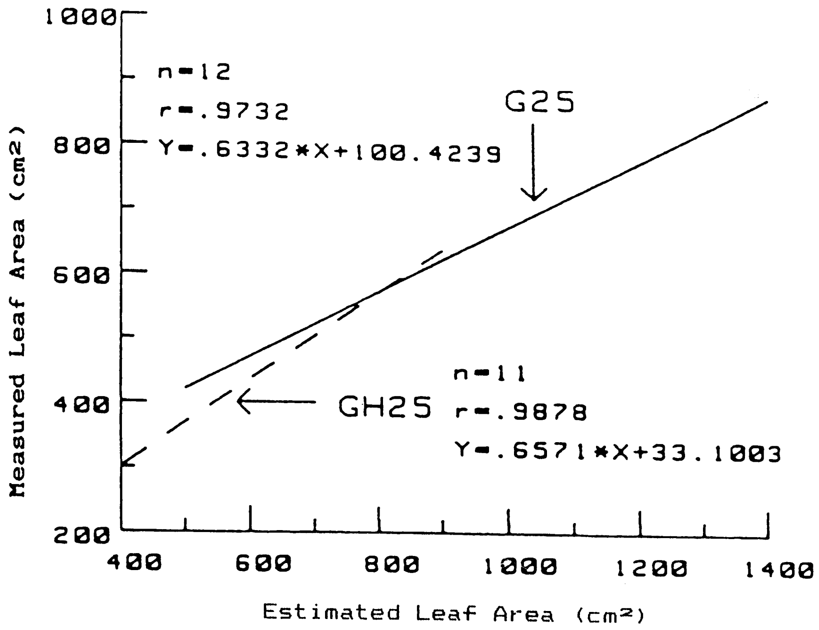

Fig 8. Age affects on the linear regressions of the estimated areas to the measured values of the 25 C-treated plants. Plants of V25 were harvested after treatment, while plants of VH25 were harvested after grown to maturity.

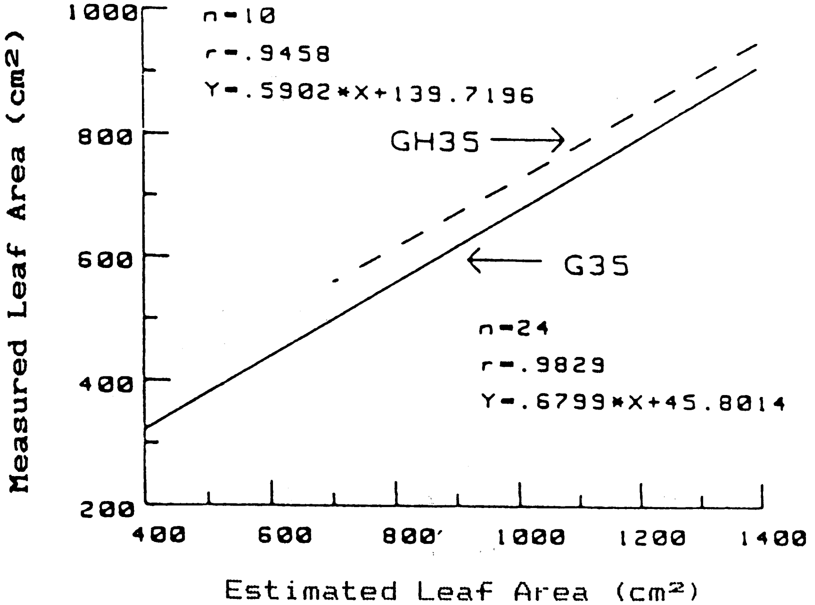

Fig 9. Age affects on the linear regressions of the estimated areas to the measured values of the 35 C-treated plants. Plants of V35 were harvested after treatment, while plants of VH35 were harvested after grown to maturity.

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株齡與溫度對水稻(*Oryza sativa* L.)葉面積之影響[1]

楊純明[2] James L Heilman[3]

摘要

本試驗在研究水稻之葉面積測定值和估計值間之相關，以及株齡和溫度對此一關係的影響。結果顯示，在控制環境下，葉面積測定值和估計值間有顯著相關。因此，在水稻全生育期內之葉面積，可藉由葉長與葉寬之測量來估算其實際值。但是當經過溫度處理後，則因葉長與葉寬間之比例變更，而改變葉面積測定值和估計值間之關係。所以，當水稻生長期間因溫度發生顯著差異時，應實施測試及迴歸分析，重新確定兩者之關係，才能據以使用估計值估算實際之葉面積。

關鍵詞：葉面積，葉齡，溫度，水稻，*Oryza* sativa L.

1. 臺灣省農業試驗所 研究報告第 1533 號。
2. 臺灣省農業試驗所副研究員，臺中縣霧峰鄉 41301 萬豐村中正路189號。
3. 副教授，美國德州農工大學土壤暨作物系。Dept of Soil & Crop Sic., Texas A & M Univ., College Station, Texas 77843, USA

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玉米普通型及南方型銹病抗病族群之評估[1]

盧煌勝[2] 蔡武雄[3] 謝光照[2] 何千里[2]

摘要：自玉米普通型及南方型銹病抗病族群 C_0 世代，逢機取得580個自交系統，經普通型及南方型銹病抗病性檢定結果，普通型銹病抗病性平均爲54.9%，變異係數爲31.4%；南方型銹病抗病性平均爲 50.0%，變異係數爲 39.0%。在廣義遺傳率方面，普通型銹病抗病性爲80.4%；南方型銹病抗病性爲52.2%。普通型銹病抗病性與南方型銹病抗病性間爲顯著正相關 (r＝0.3407)。試驗結果顯示：本族群可藉 S_1 自交後裔輪迴選種法，針對普通型及南方型銹病之抗病性與 S_1 系統之產量，同時進行選拔，以逐步集中抗病及高產基因。

關鍵詞：玉米，普通型銹病，南方型銹病，抗性，廣義遺傳率，S_1 自交後裔輪迴選種，族群改良。

玉米最主要的銹病有三種，分別爲 *Puccinia sorghi* Schw. 引起之普通型銹病(common rust)、*P. polysora* Underw.引起之南方型銹病 (southern rust) 及 *Physopella zeae* (Mains) Cummins and Ramachar. 引起之熱帶型銹病 (tropical rust) [25]。本省栽培玉米，迄今發現有普通型及南方型兩種銹病[12,31,32]。

低溫 (16-23°C) 又高濕 (100%) 最有利於普通型銹病之發育與傳播。玉米對普通型銹病之抗病性，概可分爲特殊抗病性 (specific resistance) 及一般抗病性 (generalized resistance) 二種[10]。特殊抗病性爲一種質的表現 (qualitatively expressed)，在幼苗期及成株均可發現此種抗病性，其特徵係在病原菌感染後，呈現極小之病斑 (minute chlorotic flecks)，此類抗病性受一對基因 (monogene) 控制，對病原菌之一個或少數個生理小種 (physiological races) 獨具效果，因此，某些玉米基因型對部分生理小種獨具抗病性，而另外一些基因型則對其他部分生理小種具抗病性，此種抗病性也稱爲垂直抗病性 (vertical resistance)。一般抗病性通常受爲數較多之微效基因 (polygene) 所左右，此種抗病性顯現多種病斑型態 (lesions)，同時對大多數之生理小種均具效果，故稱爲水平抗病性 (horizontal resistance) 或部分抗病性 (partial resistance)。此二種抗病性之來源，存在於許多玉米自交系或品種中[2.4.5.8-11.13-20.29.31.32]。Headrick and Pataky[6] 利用 *P. sorghi* 不同菌株夏胞子 (urediospore isolates) 混合接種於溫室栽培之 5～6 葉齡之玉米植株上，結果發現：普通型銹病在某些部分抗病性成分 (components of partial resistance) 上，在幼苗反應和在田間成株的反應頗爲近似。Pataky[17] 認爲此結果將使溫室幼苗檢定一般抗病性深具發展潛力。

南方型銹病最易於高溫 (27°C) 高濕之環境下猖獗，*P. polysora* 亦具有許多生理小種，玉米對每一生理小種之抵抗性，分別受單一基因所控制，其作用或爲完全顯性(complete dominance)、部分顯性 (partial dominance)、或無顯性 (no dominance)[3.23.26.27]。目前已鑑別出 Rpp_1-Rpp_{11} 等11個基因，其中 Rpp_9 非常接近 Rp_1^d 基因座 (Rp_1^d 座落於第十對染色體上，主控普通型銹病之

1. 臺灣省農業試驗所　研究報告第 1534 號。
2. 本所農藝系研究員、助理研究員及助理。
3. 本所植病系研究員。臺灣省　台中縣　霧峰鄉。

抗病性）。在育種工作上，西非及東非地區曾藉助這些顯性或不完全顯性之抗病基因，成功地解決了南方型銹病之問題[28]。

玉米銹病之防治，以栽植抗病品種最爲安全、經濟、有效。本省栽培玉米，不論飼料、青割或超甜玉米，面積均正快速擴增中，爲防患銹病所造成之嚴重損失，育成抗銹病玉米品種乃是當務之急。目前本省推廣品種台農351號及台農 1 號飼料玉米對普通型銹病均具抗性，然對南方型銹病則無任何抗病品種可資栽培。農試所於民國73年間引進34個玉米族群，隨即於1,736個 S_1～S_3 系統中檢定南方型抗銹病基因，並將具抗病基因之個體進行逢機交配，形成抗銹病族群，本研究即將此族群作一評估，以瞭解其在玉米抗銹病育種上可能之應用範圍，俾供玉米育種工作者參考。

材料與方法

本研究所使用的材料爲抗銹病族群C_0 逢機取得之580個自交果穗。抗銹病族群係利用具普通型抗病基因之34個族群之1,736個 S_1～S_3 系統，經南方型銹病抗病性檢定結果，在 Maize Pathological Population No. 2,4,6,7,10,11及 Suwan DMR Source 11(S)C_1 等 7 個族群各得一抗病反應植株，自交得果穗 7 枚。75年春作，將此 7 枚果穗之2,135粒種子全數播種，得幼苗1,946株，於生長箱中(28°C)以南方型銹病之病原接種，經24小時後移出生長箱，並移植於田間，作持續30天之發病調查，結果選獲抗病植株101株，遂將之逢機交配三次，並自每穗取等量種子混合，而形成C_0 世代之抗銹病族群。34個玉米族群 Pioneer Hybrid 6181、Thai. Comp. No.3(S)C_5(M)C_1、Maize Pathological Populations No. 1～12、Suwan DMR Source 11(S)C_1、Suwan DMR Source 12(S)C_1、KUC_1 (ME)C_3(S)C_1、Suwan-1(S)C_8、Suwan-2(S)C_6、Caripeno DMR(S)C_5、Amarillo Dentado DMR BC_3F_5(S)C_1等21個族群，係於民國73年春自泰國 Kasessart 大學引進；另外，PR-83A-309、PR-83A-310、PR-83A-312、PR-83B-803、PR-83B-806、PR-83B-807、PR-83B-808、PR-83B-817、TL-83A-1309、TL-83B-1802、TL-83B-1809、TL-83B-1810等12個族群，亦於73年春自墨西哥國際玉米小麥中心（CIMMYT）引進；Population 31 x Suwan 2(S)C_5(BC_1)係由二優良族群經雜交改良而成。

病菌之培養係採用 Yeh[31] 之改良離葉法（detached leaf method），先於消毒過之培養皿（直徑 9 ㎝）內放一層薄棉花，上面再加一層濾紙，然後以蒸餾水加蔗糖（5 %，v/w）及 Kinetin（20 μg/ml）之溶液潤濕備用。感病品種超甜玉米236號栽培於溫室，取其新鮮葉片先以自來水洗去表面塵垢，再用剪刀裁成長度約 7 ㎝之片段，並以乾淨之濾紙或衛生紙吸去表面多餘之水份後，置於前述準備好之培養皿內，葉片之上表皮向上。從田間採集之病葉，取其新鮮夏胞子以含展著劑（Tween 80,100μg/ml）之無菌蒸餾水製成胞子懸浮液，其濃度約爲2×10^4 spores/ml，最後再以經過殺菌之軟毛毛筆沾此胞子懸浮液均勻塗抹在培養皿內之葉片上，在室溫（24-28°C）經過 7 ～10天後即會有新的夏胞子堆及夏胞子產生，反覆進行以繁殖夏胞子，直至有足量之夏胞子供接種之用爲止。

檢定方法，乃以長 10㎝ 寬 15㎝ 之塑膠袋裝消毒土後種植供試材料置於溫室，每袋 3 株，當玉米具 3 ～ 4 片展開葉時，用上述之接種源（2×10^4 spores/ml），以花卉栽培用小型指壓式塑膠噴霧器接種，然後以透明塑膠布覆蓋保濕24小時後除去，南方型銹病保持在 24-28°C[22]，普通型銹病保持在 20-24°C 經過 6 -10 天後調查病斑形態，無肉眼可見之病徵或爲退綠色黃斑者爲抵抗型（R），黑色壞死小點到小形夏胞子堆者爲中間型（M），夏胞子堆完全發育並產生許多夏胞子者爲感病型（S）[22,26]。

自C_0世代族群逢機580個自交果穗，即爲580個自交系統（S_1 family），分別進行南方型與普通型銹病之抗病性檢定。試驗均採 Replication within block 設計，每一區集包括10個系統，重複二

次，共計58個區集。每個系統之每重複種植 9 株，分裝 3 袋。南方型及普通型銹病之抗病性，係以每系統中抗病植株百分比紀錄之。資料經變方分析，估算變異係數（coefficient of variation, cv）、平均值（mean, $\bar{x}$）、頻度分佈（frequency of distribution）、基因型變方成分（component of genotypic variance, $\hat{\sigma}_g^2$）、環境變方成分（component of environmental variance, $\hat{\sigma}_e^2$）及廣義遺傳率（broad sense heritability, $\hat{h}_b^2$），$\hat{h}_b^2 = \hat{\sigma}_g^2 / (\hat{\sigma}_g^2 + \hat{\sigma}_e^2 / r)$，r 爲重複次數。

結果與討論

本省栽培玉米遭受普通型銹病及南方型銹病侵害造成之減產損失雖未經精確統計，但有關此二型銹病的發生早已受到研究者的注意[12.31.32]。過去由於種植面積較小，而且種植季節多集中在秋裡作，玉米生長期間氣溫低，適合普通型銹病之猖獗，卻不適合南方型銹病的滋長，因此普通型銹病似乎比南方型銹病更受重視。目前本省全年玉米栽培面積已超過八萬公頃，而且春秋作並重，春作初期及秋作末期之低溫正適合普通型銹病的蔓延，又春作末期及秋作初期之高溫則適合南方型銹病之危害；尤其超甜玉米推廣之後，農民整年均作不定期的栽培，致使普通型及南方型銹病之接種源終年不斷，對本省玉米生產將構成極嚴重的威脅。由於栽培抗病品種是病害防治中最經濟、安全、有效的方法，臺灣省農業試驗所乃致力於抗銹病育種工作之進行。實際育種工作上，普通型及南方型銹病種源之搜集，除了栽培種玉米外，亦可在多年生之大芻草(*Eucklaena perennis* Hitch.)及許多一年之大芻草(*E. mesicana* Schrad.)找到抗病基因，並藉雜交加以導入利用。在飼料玉米自交系OH43及C103中之部分抗病性，則常被用來作爲甜玉米抗銹病育種之最佳抗源[30]。本省在抗病種源之篩選方面，Yeh 曾於本省玉米材料發現普通型銹病之抗源[31.32]；至於南方型銹病之抗源，則未能確定。

近年來，本所積極自國外引種，在34個具普通型抗病基因之玉米族群中，檢定得抗南方型銹病植株，復經逢機交配三次形成抗銹病基礎族群。爲了進一步瞭解此一抗銹病族群的特性及其可能利用方式，乃自 C_0 世代逢機取得580個自交系統，進行南方型及普通型銹病之抗病檢定。試驗結果顯示：普通型銹病之抗病性頻度分佈介於 0 ～10.0％之間的有64個系統，介於10.1～20.0％之間的爲24個系統，20.1～30.0％者爲33個系統，30.1～40.0％者爲36個系統，40.1～50.0％者爲86個系統，50.1～60.0％者爲45個系統，60.1～70.0％之間者最多，爲104系統，70.1～80.0％爲96個系統，80.1～90.0％者爲56個系統，而90.1～100.0％者最少，僅爲19個系統。580個系統之普通型銹病抗病性平均爲54.9％，變異係數爲31.4％（圖 1 ）。在南方型銹病方面，抗病性之頻度分佈介於0～10.0％者有6個系統，10.1～20.0％者31個系統，20.1～30.0者爲64個系統，30.1～40.0％者爲92個系統，40.1～50.0％者爲110個系統，50.1～60.0％者爲48個系統，60.1～70.0％者爲117個系統，70.1～80.0％者爲62個系統，80.1～90.0％者爲29個系統，90.0～100.0％者僅有7個系統。580個系統之南方型銹病抗病性平均爲50.0％，變異係數爲39.0％（圖 2 ）。普通型銹病及南方型銹病之抗病性之頻度分佈均似常態，平均值相近，變異則以南方型銹病之抗病性稍大。

經變方分析結果，普通型及南方型銹病之抗病性之重複／區集及系統／區集二項均極顯著(表1)。普通型銹病抗病性之基因型變方成分爲583.3；南方型銹病抗病性爲214.3。普通型銹病抗病性之環境變方成分爲 284.1；南方型銹病抗病性爲 392.9。在廣義遺傳率方面，普通型銹病抗病性爲80.4％；南方型銹病抗病性爲52.2％。二廣義遺傳率均顯著異於0，而普通型抗病性之廣義遺傳率則顯著大於南方型銹病抗病性之廣義遺傳率（表 2 ）。

有關 *P. sorghi* 引起之普通型銹病之抗病性遺傳，Mains 早在 1931 年即檢定出一個顯性抗病基因[15]，其後多位研究者亦發現此類特殊抗病性多屬一對顯性基因所控制。同時，多數的抗病基因經鑑定結果，均座落在第十對染色體之短臂上，有部分研究者亦在其他染色體上發現此類抗病基因[10.16.21]。抗病基因，除了上述之顯性基因之外，另有一對不完全顯性基因（single incompletely

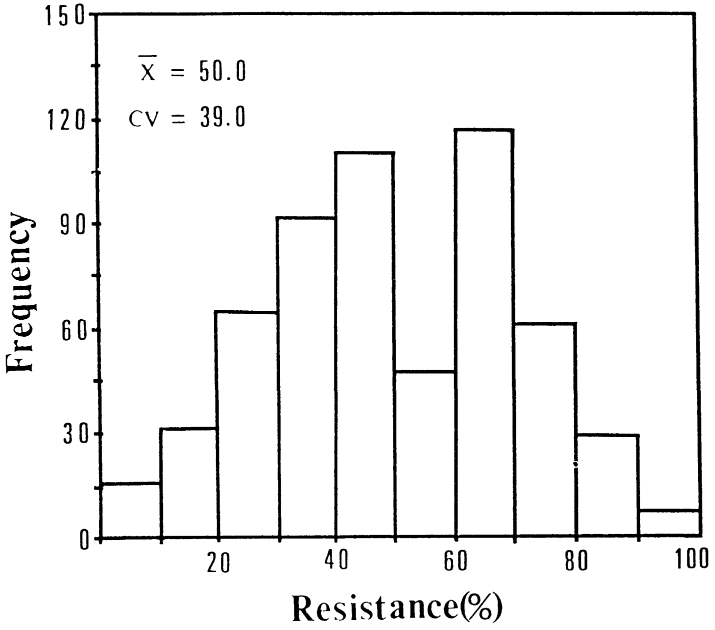

Fig. 1. Distribution of common rust resistance (%) of 580 S_1 families.

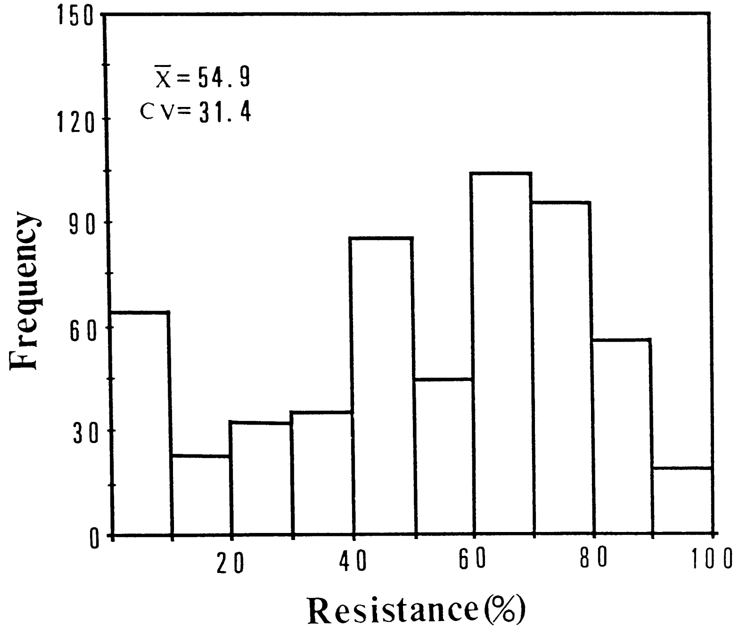

Fig. 2. Distribution of southern rust resistance(%) of 580 S_1 families.

Table 1. Analysis of variance for common and southern rust resistance (%).

Sources of variation	df	Mean squares	
		Common rust	Southern rust
Blocks	57	1886.8	1656.6
Replications/Blocks	58	348.4 **	1667.7 **
Families/Blocks	522	1450.6 **	821.4 **
Pooled error	522	284.1	392.9

** : Significant at 1 % level.

Table 2. Estimates of variance components and broad sense heritability for common and southern rust resistance (%).

Estimates	Common rust	Southern rust
$\hat{\sigma}^2_g$	583.3	214.3
$\hat{\sigma}^2_e$	284.1	392.9
$\hat{h}^2_b$	80.4 (76.8, 83.5)$^+$	52.2 (43.2, 59.7)

$^+$: Confidence intervals at 95% level for $\hat{h}^2_b$ estimates are presented in parenthesis.

dominant），一對隱性基因（single recessive），雙重隱性基因（duplicate recessives）及三重隱性基因（triplicate recessives）等都曾被發現過[8.14.16]。一般而言，幼苗期之抗病性多屬特殊抗病性，成株抗病性則以微效基因控制之一般抗病性或部分抗病性者居多[2.4.7.10.13.17]。南方型銹病之抗病性主要亦受一對顯性基因控制，部分則是不完全顯性[3.23.26.27]。由於 *P. polysora* 存在許多生理小種，常使單一抗病基因難達抗病效果。美國玉米帶之經驗顯示，一般抗病性之應用，可有效控制玉米之普通型銹病，而得以避免因此病造成之減產損失[10]。Van der Plank[30] 亦指出，在商業化生產上，農作物利用一般抗病性對絕對寄生菌（obligate parasite）引起之病害應屬最爲有效。因此，不管是普通型或南方型銹病，凡屬於一般抗病性之各種現象，如田間抗性（field resistance）、成株抗性（adult plant resistance）、部分抗性、延遲產孢抗性（slow rusting resistance）等之研究均普遍受到重視[1.8.9.13.24.30]。

許多育種家在從事玉米抗銹病育種之過程中，均將選拔較高水準之一般抗病性定爲首要步驟，其次再利用回交法導入特殊抗病性基因。如此可較長期維持抗病性之穩定性，而不使銹病嚴重猖獗。美國玉米帶許多抗銹病玉米品種即依此方式育成[4.19]。Hooker[10] 曾建議將廣泛之幼苗抗病性單一顯性基因（如 "Cuzco gene" 等)及成株抗病性基因，同時導入目前或未來之雜交種中，如此才能有效避免普通型銹病對玉米產業之破壞。另外，根據許多研究者的經驗[3.14.19.23.24.30]，不論普通型或南方型銹病之抗病性，顯性及累加性（additive effect）遺傳變方同具重要的影響效果，因此許多型式之輪迴選種法（recurrent selection）及相互輪迴選種法（reciprocal recurrent selection）均可有效地增進抗病性。

普通型銹病抗病性之廣義遺傳率估值通常介於65.4～89.7%之間[19]。本族群普通型銹病抗病性之廣義遺傳率估值亦在此範圍內，相信自分離族群中進行抗病單株選拔，效果必然也高。Hooker[8.9]、Kim and Brewbaker[13] 在飼料玉米抗普通型銹病育種工作中，即有類似成功的例子。至於南方型銹病，抗病性之廣義遺傳率估值並不很高，顯示其受環境影響較大，自分離族群中逕行抗病單株選拔，效果較難掌握。由於普通型銹病及南方型銹病對本省玉米栽培具有同等之威脅性，育成之新品種兼

具兩種銹病之抗病性，較爲理想。本族群中普通型銹病及南方型銹病之抗病性間具有顯著正相關（r＝0.3407），選拔二種抗病性並不互相衝突。又目前玉米推廣多以雜交種爲主，自交系必須具備較高之組合力及合於雜交種子生產之產量潛力，因此，利用 S_1 自交後裔輪迴選種法（S_1 progeny recurrent selection)進行族群改良（population improvement）應爲可行。在實際育種工作中，可於每一循環中，種植約5,000株 S_0 玉米植株，於田間自然接種情況下，選拔農藝性狀優良者，令其自交，最後決選200株 S_0 植株，並分別收穫其自交果穗成200個 S_1 系統。此200個 S_1 系統即分別於溫室進行普通型及南方型銹病之抗病性檢定，並於田間進行 S_1 產量比較試驗。根據抗病性檢定及產量試驗成績，選拔40個（20%）抗病性強且高產之系統，並將其上季留存之 S_1 系統種子進行逢機交配，以生產次一循環選種所需的種子。如此當能逐步集中有利基因，增強抗病能力，同時兼顧自交系之產量潛力。

本研究中所用之接種源，不論普通型或南方型銹病，均採集自田間，再經試驗室培養而得，大致上可視爲各生理小種之混合病源。此項接種源之製備方法頗爲簡便，育種上，進行大批材料篩選時，可達到一定的效果。但因未經個別生理小種鑑定，接種源中所含生理小種之種類或未完全，同時每一種類所佔之比例亦難一致，此點，在未來接種源的收集方面，或許應從地點的增加，以及每地點採集樣品（病葉）量的擴大來加以改善。

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Evalution of Base Population Resistance to Common and Southern Rust in Maize[1]

H. S. Lu[2], W. H. Tsai[3], G. J. Shieh[2], and C. L. Ho[2]

Summary

Evaluations of 580 S_1 families of base population of resistance to common rust (*Puccinia sorghi* Schw.) and southern rust (*P. polysora* Underw.) in maize (*Zea mays* L.) were conducted in seedlings in greenhouse experiments. Means and coefficients of variation were 54.9% and 31.4%, respectively, for common rust resistance;and 50.0% and 39.0%, respectively, for southern rust resistance. Heritability estimates were 80.4% and 52.2% for common and southern rust resistance, respectively. Resistance to common rust was significantly correlated with resistance to southern rust (r=0.3407). This results indicate that S_1 progeny recurrent selection could be utilized to maximize progress for increasing common and southern rust resistance and yield potential.

Key Words : Maize, Common rust (*Puccinia sorghi* Schw.), Southern rust (*P. polysora* Underw.), Resistance, Broad sense heritability, S_1 progeny recurrent selection, Population improvement.

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1. Contribution No. 1534 form Taiwan Agricultural Research Institute.
2. Respectively, senior agronomist, assistant agronomist and research assistant, Department of Agronomy, TARI.
3. Senior plant pathologist, Department of Plant Pathology, TARI, Wufeng, Taichung, Taiwan 41301, ROC.

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大豆種源葉片性狀之遺傳變異及其與產量之關係[1]

詹國連　魏趨開　林順福[2]

摘要：爲欲瞭解更多大豆葉片性狀及其與產量的關係，本所於75年春作及夏作種植大豆種源1,500品種（系）（來自16個國家及包含10個成熟期群）。每一種源種一行，行長1 m，行距0.55m，每行播種20粒。調查的性狀包括末端小葉（即複葉中央之一片）之長、寬，及單株種子產量。於每株中央部位取一片末端小葉（以下均稱葉片），每種源取3株供葉片測量用。另外，每種源再取5株供調查單株種子產量用。所有葉片及植株之選取，均以逢機行之。又爲求增加樣本估值之精確性，本研究採用分層取樣法（Stratified random sampling method），由各成熟期群中取1／10，共計取得150樣品（品種，系）爲本研究用材料。茲列出兩期作試驗結果摘要如下：㈠五項研究性狀的介值有葉寬、葉大小及產量等三項是春作大于夏作，但其變異（cv）均是春作小夏作大。㈡春作之葉長、葉形（長／寬）與產量呈極顯著的負相關；葉寬、葉大小則與產量之相關不顯著。但夏作之葉長、葉寬及葉大小，與產量均呈極顯著之正相關。㈢四項葉片性狀，在兩期作間之相關皆不顯著，但產量在兩期作間之相關，達極顯著水準（r＝0.286 **），後者顯示春作產量高之種源，在夏作時亦然。㈣參試種源依葉大小分，有大、中、小三類；依葉形分有闊葉、中間、狹長三型。以中大葉及中間型葉的種源佔多數（各佔48％及46％）。㈤三種葉大小種源的產量（g/plant），春夏兩期作皆以大葉品種的最高（春作爲14.14，夏作爲14.52），中大葉者次之（11.02及9.11），小葉者最低（8.84及6.09）；且三者間的產量，在各期作之差異均顯著。㈥三種葉形種源的產量，春作依序爲中間型＞闊葉型＞狹長型；夏作依序爲闊葉型＞中間型＞狹長型；但三者間產量的差異，在春作不顯著，在夏作則顯著。㈦由本試驗結果得知，無論春作或夏作，葉面積較大，葉形爲闊葉型或中間型之種源，其產量有顯著增加之趨向，可供育種、研究及栽培之參考。

關鍵詞：大豆、種源、葉形、中央小葉、分層取樣、簡單相關、遺傳變異、產量。

常見的大豆葉片，依小葉（Leaflet）大小分，有大、中、小三類，依小葉形狀分，有狹長、中間、闊葉三型[7,16]。由各器官生育期乾物質分配率的大小，知葉片爲大豆光合作用重要器官[7]；特別在種子充實階段豆莢所在部位的葉片，爲其光合產物的主要供源[1]。試驗亦證實大豆地上部枝條（葉片），控制根瘤氮素固定作用，而葉片供給根瘤光合成產物量的增加，可增加氮素固定之能力與種子產量[19]。而無限型大豆品種開花期後之營養生長，尤其是葉片生長勢力的大小，爲控制子實重的主要因子[10]。

與其他作物相比，大豆（葉片）較易受到生長因子（季節、部位、光線等）的影響。不同小葉大小品種之葉數、葉面積、種子乾重等，在不同期作及葉片大小間之表現，多有顯著差異[7]；而且，不但親本品種的葉片性狀，在不同節位有甚大差異，其 F_2 族群個體葉片性狀之變異程度，均依主莖節位之上升而增大[2]。

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1. 臺灣省農業試驗所　研究報告第 1535 號。本所大豆種源計畫，三十年來承前農復會、農發會及今之農業委員會資助特此感謝。

2. 各別爲本所農藝系助理研究員、助理及助理。臺灣省　臺中縣　霧峰鄉。

在光線利用上，大葉及小葉品種植株不同剖面的幅射光，由葉群（Leaf canopy）上層向地面變弱，而且，此一現象係與品種有關[18]。三種葉形及株型品種之葉群結構（Canopy architecture），對陽光的利用與大豆生育及收量的影響曾被研究[9]。又以去葉去莢處理研究光合成產物始源大小對產量之影響，亦多有報導[1,10]。研究者亦指出，植株乾物重與葉面積成高度相關（r=0.91），可供大豆選種之重要指標[17]。顯然，研究並獲得理想的葉面積或葉群結構，俾提高光合效率，進而增加產量，為改良大豆之重要途徑。

本研究之主要目的，在探討大豆種源葉片性狀之遺傳變異及其與單株產量（以下均稱產量）之關係，俾供育種、栽培及研究之參考。

材料與方法

一、試驗材料：

本所於75年春作及夏作種植1,500種源[5]，供種子更新及調查之用，該1,500種源來自16個國家，並包含十個（即00、0…………、Ⅶ、Ⅷ）成熟期群（係在美國之分類），其中00群之品種適合于緯度甚高之加拿大南部地區栽培，其餘依序南移至緯度較低之地區，第Ⅷ群適合於沿墨西哥灣各州栽培[12]。為求增加取樣種源代表性，本研究採用分層取樣法（Stratified sampling method），自各層（群）中取10%，共計取樣種源150品種（系）為本研究用之材料。其來源、成熟期群及品種（系）數列如表 1。

表 1. 供試種源之來源、成熟期群及品種數

Table 1. The origin, maturity group and number of varieties of soybean germplasms planted in 1986.

Origion	Maturity group									Tatal
	00	0	I	II	III	IV	V	VI	VII	
Belgium	1	3	2	1						7
Canada			1							1
China		1	4	24	20	6	2	2	1	60
France	2	2	2		1					7
Germany	1	1								2
Holland		1								1
Italy			1							1
India								1	3	4
Indoseia									1	1
Japan	1		2	3	11	5	1	1	2	26
Korea			1	2	4	5	3			15
S. Africa								1		1
Sweden	3	1								4
USA	1			1	3	1	2	1		9
USSR			1							1
Unknown		3	1	2	1	1	1	1		10
Total samples	9	12	15	33	40	18	9	7	7	150
Sum of germplasms planted	94	117	158	322	400	184	90	66	69	1,500

Remarks: Soybean germplasms (genotypes) are classified into maturity groups (00, 0, I,………,Ⅷ) corrsponding roughly to belts of latitude, e.g. genotypes of maturity group 00 are adapted to the northern limits of production in Canada, while those in maturity group Ⅷ are adapted to production areas of Gulf Coast[12].

二、試驗方法：

單行區、行長1公尺，行株距55×10公分，每穴播2粒。春作于1月17日、夏作于7月18日播種。肥料用量爲N：P_2O_5：K_2O=25—70—95 kg/ha，於第二次耕犁碎土時，作基肥一次撒施。生育期間進行中耕除草及培土（一次），並適時防治病蟲害及灌溉等作業。

當大豆葉片完全展大時（R_4～R_5）[1.14]，于每行取樣3株，並於植株中高部位[2]（全株分成上、中、下三部位），取一片複葉，量取末端小葉（Terminal leaflet）(以下均稱葉片）之長度（最長處）、寬度（最寬處），以公分記錄之[14]。次於植株莢果種子完全成熟（R_8）[5] 時，每行割取5株，調查單株產量。所有取樣之植株及葉片，均以逢機行之。然後以各別之觀測值進行統計分析，探討其變異（Variation）、及葉片性狀與產量之相關性（Simple Correlation），並比較各類葉片大小及葉形之產量（g/plant）間差異，後者採用柯氏（Cochran,1964）加權 t′ 法[13]測驗之，其統計公式爲：

$$t' = (\bar{x}_1-\bar{x}_2)/\sqrt{S_1^2/n_1+S_2^2/n_2}$$

其顯著值：$t' = (W_1t_1+W_2t_2)/(W_1+W_2)$.

上式中 $\bar{x}_1$、$\bar{x}_2$；S_1^2、S_2^2； n_1、n_2 及 t_1、t_2 各別爲不同類型葉大小或形狀之產量平均值、均方（mean square）、樣品數及其顯著之 t 值。又 $W_1=S_1^2/n_1$，$W_2=S_2^2/n_2$。

結　　果

一、試驗期間的氣象資料：

本試驗兩期作的氣象資料列如表2。由該表知春作大豆全生育期的溫度變化，由初期的低溫轉變至後期的高溫（15—26°C），而夏作溫度（29—25°C）的變化，恰與春作相反，生育初期爲高溫，漸至後期溫度漸減。春、夏二期作的日光照射量，亦有明顯差異，其變化趨勢與溫度略似。至於雨量方面，春作全生育期之雨量較多（3—10㎜/day），尤以生育中、後期（5～6月）爲多（10—8㎜/day）；但夏作之雨量少（7—3㎜／day），且多分配于生育初期，中後期漸少，與春作有相反趨勢。由該三項氣象因子在春、夏作之差異情形觀之，對環境敏感的大豆，其葉片及產量等性狀之表現，勢將受到嚴重影響。

表2. 臺中地區民國75年之平均氣溫、日射量及雨量

Table 2. Mean temperature (°C), solar radiation (cal/cm²/day) and precipitation (㎜/day) during the experimental period in Taichung, Taiwan, 1986.

Weather	Spring crop season						Summer crop season					
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temp.	14.7	14.9	18.5	23.6	25.4	27.6	28.7	28.7	27.1	24.6	21.7	18.0
S.R.	270.0	187.0	254.0	292.0	302.0	393.0	415.0	403.0	407.0	340.0	274.0	256.0
Preci.	2.8	2.9	4.7	2.4	10.9	8.7	7.7	9.5	3.5	—	2.5	0.6

Temp.：Temperature; S.R.：Solar radiation：Preci.：Precipitation.
資料來源：臺灣省農業試驗所農業氣象站

二、種源葉片性狀及產量之變異

供試大豆種源葉片之長、寬、面積，（L×W）、形狀（L/W）及產量（Yield, g/plant）等五項性狀，在春作及夏作之介值（Statistics)，各有甚大差異（表3）。以平均值而言，葉片長度（㎝）是春作較短，夏作較長（8.7對9.9）；葉寬（㎝）則是春作較寬，夏作較窄（7.2對4.7）；葉面積（㎠）與葉寬相似，亦是春作較大，夏作較小（63.7對45.8）；葉形或葉片長寬比（L/W），則是

春作小於夏作（1.21對2.11）；單株產量（g/plant）亦是春作高，夏作較低（11.0對9.3）。但五項性狀之變異係數（cv），均是春作小（8.5%—56.5%）、夏作大（15.4%—58.6%）；其中產量的變異係數，無論在春作或夏作均大于50%，顯示產量性狀在春夏作均有較大之遺傳變異。

表 3． 葉片性狀及產量在各期作之變異

Table 3. Coefficient of variations of terminal leaflet characters and yield of soybean germplasms in different crop seasons.

Crop Season	Statistics	Length (cm)	Width (cm)	Size (cm², LXW)	Shape[1] (L/W)	Yield (g/plant)
Spring	mean	8.7	7.2	63.7	1.21	11.0
	min.	6.2	5.2	34.0	1.01	0.5
	max.	11.2	8.6	86.9	1.66	29.4
	med.	8.7	7.3	63.2	1.20	9.8
	c.v. (%)	9.6	8.5	15.7	9.30	56.5
Summer	mean	9.9	4.7	45.8	2.11	9.3
	min.	6.1	2.9	20.1	1.32	1.0
	max.	13.8	8.3	105.4	3.02	37.5
	med.	9.9	4.7	46.0	2.07	8.3
	c.v. (%)	16.2	20.7	34.4	15.41	58.6

[1] The leaflet shape or L/W ratio of broad, intermediate and narrow terminal leaflet are 1.1—1.9, 1.9—2.3 and 2.3—3.0 respectively showed in Table 6. In general, the larger the ratio, the longer the leaflet is expected.

三、種源葉片性狀及產量之相關

由表 4 所示，春作之葉長（L）與葉形(L／W)二性狀與產量均呈極顯著的負相關（r＝－0.165 ** 及－0.237 **），顯示葉愈長，或葉形愈細時，產量愈低；葉寬（W）、葉大小與產量之相關性（r＝0.53及－0.075）不顯著。在夏作時，葉長、葉寬及葉大小等三性狀與產量均呈極顯著之正相關關係（r＝0.64 **，0.514 **，0.618 **），即葉愈長、愈寬、愈大，產量便愈高，與春作之表現有相反趨勢。

表 4． 葉片性狀與產量在各期之相關

Table 4. Correlation coefficients of terminal leaflet characters and yield of soybeans in different crop seasons.

Crop Season	Character	Yield (g/plant)
Spring	Length , (L)	−0.165 **
	Width, (W)	0.053^{ns}
	(L × W)	-0.075^{ns}
	(L/W)	−0.237 **
Summer	Length, (L)	0.648 **
	Width, (W)	0.514 **
	(L × W)	0.618 **
	(L/W)	0.015^{ns}

** : Significant at 1% level

四、期作間葉片性狀與產量之關係

前兩節述明葉片性狀及產量等性狀，在春夏作之變異及其相關性。今進而欲探知該等性狀，各自

在兩期作間表現之相關程度（表5），該表顯示，四項葉片性狀，〔葉長（L）、葉寬（W）、葉大小（L×W）及葉形（L/W）〕，在期作間之相關皆不顯著，亦即在春、夏作間之表現無一致性。但兩期作間產量之相關性極顯著（r＝0.286 **），顯示在春作產量較高的種源，在夏作亦然，此爲一甚重要之結果。

表5. 葉片性狀及產量在春、夏兩期作間之相關

Table 5. Correlation coefficients of terminal leaflet characters and yield of soybeans between spring and summer crop seasons.

Length (L)	Width (W)	Size (L×W)	Shape (L/W)	Yield
0.009^{ns}	0.127^{ns}	0.070^{ns}	-0.045^{ns}	0.286 **

** : Significant at 1% level.

五、種源葉片大小及形狀之分類

由上節得知產量高的種源在期作間有正的相關關係，吾人似宜探明究是何種葉片類型的種源，有此項相關性，則此項結果將更明確、更具意義。因而依葉大小、葉形分類之（如表6）。分類結果，就葉片大小而分，有大中小三類。參試品種中有46品種屬於大葉類（Large），其葉面積爲11.9～15.0 cm²；有72品種屬于中葉類（Medium），其葉面積爲4.7～11.8cm²；另32品種之葉大小爲1.0～4.6cm²，屬于小葉類（Small）。概言之，參試種源中以中葉類的品種居多，大葉者次之，而以小葉類的品種數最少。

表6. 參試種源葉片小大及形狀之分類

Table 6. Classification of terminal leaflet size and shape of soybean germplasmas based on spring planting 1986, in Taichung, Taiwan.

Item	Size (L×W, cm²)			Shape (L/W)		
	Small	Medium	Large	Broad	Intermediate	Narrow
Level	1.0～4.6	4.7～11.8	11.9～15.0	1.10～1.89	1.90～2.30	2.31～3.02
No. of entries	32	72	46	43	69	38
% of entries	21	48	31	29	46	25

次就種源葉片形狀（圖1）(表6）而分，有狹長型（Narrow or Lancealate）、中間型（Intermediate or Rhomboid）及闊葉型（Broad ， Ovoide or Oval）三型。參試品種中有38品種爲狹長型，其葉片長寬比爲2.31～3.02，是參試品種中葉片最長者；有69品種屬于中間型，其形狀介於狹長型與闊葉型之間，其葉片長比寬大1.90～2.30倍；再有43品種葉片之長比寬大1.1～1.89倍，屬于闊葉型。故參試種源以中間葉型最多，闊葉型（圓形或卵圓）次之，狹長型的品種最少。

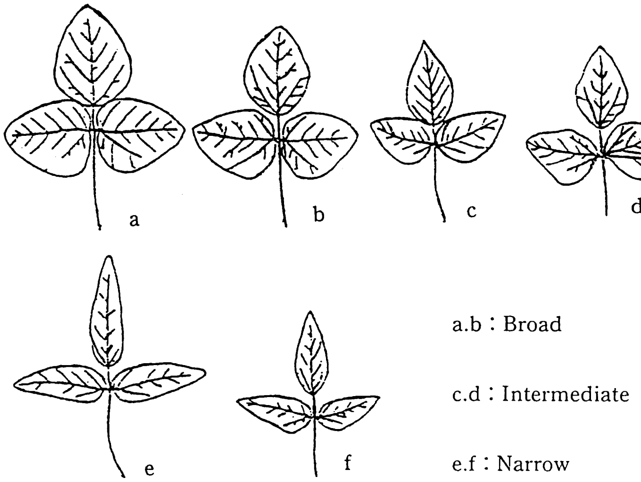

圖 1. 大豆葉片之形狀

Fig. 1. Leaves of soybean plant(11)

六、種源葉片大小及形狀別之產量比較

依照表 6 分類參試種源葉大小及葉形爲基礎，比較各別之產量後（表 7），發現三類葉大小（Large, Medium, Small）種源間的產量，春、夏兩期作皆以大葉類品種的最高，中間類次之，小葉類的最低；春作依次爲14.143、11.020及8.847g/plant，夏作時依序爲14.528、9.118及6.091g/plant，且三者間的差異在春、夏作均顯著。

表 7. 供試種源葉片大小及形狀別之產量比較

Table 7. Comparison of yield (g/plant) of different terminal leaflet size and shape of soybean germplasms.

Season	Statistics	Size (L×W, cm²)			Shape (L/W)		
		Large	Medium	Small	Narrow	Intermediate	Broad
Spring	$\bar{x}$	14.143[a]	11.020[b]	8.847[c]	1.191[a]	1.226[a]	1.200[a]
	S^2/n	0.273	0.535	0.605	0.001	0.001	0.002
Summer	$\bar{x}$	14.528[a]	9.118[b]	6.091[c]	1.964[b]	2.128[a]	2.194[a]
	S^2/n	0.856	0.343	0.247	0.002	0.002	0.003

至於三類葉型（Narrow, Intermediate, Broad）種源的產量，春作依序爲 1.191、1.226 及 1.200g/plant，即以中間型葉的最高，闊葉型者次之，狹長型葉最低，但相互間的差異不顯著；夏作則以闊葉型品種的產量最高（2.194g／plant），中間型葉居次（2.128g/plant），但前二者相互間的差異不顯著；前二者與狹長型葉之差異則顯著。

總之，三類葉大小種源之產量，春、夏作均以大葉類的最高，且相互間之差異均顯著。三類葉形種源之產量，春作以中間型的最高，但與其餘二類葉型種源間的差異不顯著；在夏作則以闊葉型及中間型葉種源的較高，且與狹長型葉產量之差異顯著。

討　論

大豆小葉（Leaflet）面積受葉大小、葉數、栽培密度及環境等之影響，其在植株各部位的分佈

也不一致，同時與品種生育期（長短）及環境（有灌漑時葉面積會較大）有關。又即使在同一成熟期群內，小葉大小及總體（Leaflet mass）均有顯著變異[10]，報告亦指出，大豆主莖上葉大小之變異，依生育時序及伸育性而不同。有限型品種於開花後葉數不再增加，其大小隨節位上升而增大。但無限型開花後，莖及葉繼續生長，葉數增加很多，不過葉之大小隨節位上升而漸增，但之後便變成狹小[20]。曾、朱[3] 亦報導，小葉面積因期作（秋＞夏＞春）及栽培密度（20cm＞10cm＞5cm）而異。是以本研究小葉之大小，顯亦受某些該等因素之影響。

典型成熟大豆末端小葉的長度為 4 —20cm，寬為 3 —10cm，變異甚大；而兩片側小葉之主脈（stalk）有時僅 1 cm或更短[11]。本研究所得種源末端小葉長為6.1—13.8cm，寬為2.9—8.6cm，與典型者頗為接近；而較傅等[6] 所得末端小葉長為 7 —12.2cm，寬為1.1—3.0cm稍大。但本研究所得種源末端小葉面積為 5 —15cm²，與盧等[7] 之 9 —48cm²，傅等[6] 之11—52cm²，以及與 IBPGR[16] 之70—150cm²，殊不一致。顯然與前段所述諸多影響因子有關。如有以每株平均小葉面積（總葉面積／3×葉數）表示者[7]；有者研究葉形性狀在品種間及主莖節位別之差異，發現主莖節位上葉形之表現，因生長發育階段之不同而有差異，同時要測定株型應以生育中期位於中節位之葉較妥，位於主莖上位及下位之葉似不適宜[2]。另者根據主莖節間及葉部性狀之生育分析，發現大豆主莖上葉型性狀之遺傳及環境變異，因葉位別之不同而有很大之差異。並認為探討葉形特徵時，不可以一株之平均值作為研究對象，而應以節位別各葉之測度值分析相互關係之生長發育型式較為妥當[6]。類此之取樣單位、取樣部位等等問題，實有待進一步探討。

次就供試種源小葉形狀（L/W）而言，本研究之分級（表 6 ）為：狹長型（長寬比大於2.31），中間型（1.9～2.3）、闊葉型（小於1.89）；與 IBPGR 所訂之標準：狹長型（長寬比2.2或以上），中間型（1.9～2.1）、闊葉型（1.8以下）[16]甚為相符。顯示葉長寬比（葉形）在不同環境下具較大穩定性。而供試種源中以中間形品種（系）最多，佔46%，闊葉型的次之（29%），狹長型的最少（25%）。至於小葉長的變域，在春夏兩期作略似，其平均是春作短，夏作長；葉形的變域及平均，與葉長近似。其次是葉寬及葉大小，春夏作之數值，與前二者相反，是春作大，夏作小。至於產量是春作高、夏作低。這與多數報導[5,7,8] 相一致，但王等[1] 謂春作乾物質分配至生殖器官之效率較差，種子之乾物質分配遠較夏季為少，可能是造成春夏作產量差異之主要原因，似有相反結果。就四項葉片性狀的變異係數而言，概是春作小（ 9 —16%），夏作大（15—34%），顯示葉片性狀在夏作環境下，變異較大；但春夏作產量的變異係數均大（56.5%及58.6%），顯示產量在兩期作均有較大之遺傳變異。

就四項葉片性狀與產量之相關（表 4 ）觀之，知其在春夏作有異。春作葉長及葉形與產量呈顯著的負相關，顯示臺灣高溫多濕的春作環境下，大豆葉片較長於產量不利；葉寬與產量無關；葉大小雖與產量無相關關係，但其值為負，暗示春作大豆之葉片不宜過大，過大則對產量不利，蓋此可能因為大葉、薄葉葉部之光合率（photosynthesis rate）較低所致[10]。但在夏作時，三項葉片性狀與產量間均呈顯著正相關，顯示該三項葉片性狀之生長量，適足以供產量生產之需。

再由供試種源四項葉片性狀，在春夏作期間的相關值均不顯著觀之（表 5 ），知其在期作間之表現無一致性，即期作間有變異，曾[2] 有類似之結果。但兩期作間產量之相關顯著，表示在春作產量高的種源，在夏作亦高，是一項令人滿意的結果。

最後，關於三類葉片大小之產量（表 7 ），發現兩期作均是大葉＞中葉＞小葉，且三者間產量之差異，在春夏作均顯著。此項結果與曾[4]，盧等[7] 之研究相符。至於三種葉型（L/W）種源之產量，在春作是中間型＞闊葉型＞狹長型，但三者間之差異不顯著；在夏作是闊葉型＞中間型＞狹長型，而且前兩型間之差異不顯著，前兩型與狹長型之差異則顯著。蘇等[9] 認為採用陽光能透過至葉群深處之窄（小）葉、少分枝型品種，配合密植栽培，可能會顯著提高單位面積產量；再者，Hsieh et

al.[15] 亦證實葉面積較一般正常葉減少30%之狹葉形大豆，具有較高的單葉光合速率，此處春作狹長型葉之產量顯然具有較佳透光性的生理基礎，值得重視。

正如 Buzzell et al.[10] 謂，大豆育種是尋求有關增加光合作用能量的可能方法，其最終目的是要因增加光合能量而增加產量，是一項值得追求的目標；而葉片形狀與光合作用能量的分配及利用，關係極為密切，故本研究獲致之結果，應可作為從事大豆育種時之參考。

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Genotype Differences in Terminal Leaflet Characters and Their Relationship to Yield in Soybean Germplasms[1]

K. L. Chan,[2] C. K. Wey[2] and S. F. Lin[3]

Summary

To learn more about the leaf characters and their relationship to yield of soybeans, a total of 1,500 soybean germplasms which involving ten maturity groups and sixteen countries were grown in spring and summer crop seasons 1986 . They were planted each in 1 m row distance with 20 seeds per row and with 55 cm row apart. Data included length and width of terminal leaflet, and yield per plant were collected. One terminal leaflet (name it as leaf hereafter) in middle position of stem was randomly measured, and respectively three terminal leaflets and five plants each row (genotype) were also randomly sampled for leaf measurement and yield weight. In order to increase the precision of the estimate of samples, stratified random sampling technique was adopted, and a total of 150 samples (genotypes) were used in the study. The experimental result were summarized as follows:

a) With the exception of leaf length and shape, the average values of width, size and yield (g/plant) were higher in spring than in summer crop season. The coefficients of variation of the four leaf characters (length, width, size (L×W) and shape (L/W)) were low (8.5-15.7) in spring and high (15.4-34.4) in summer crop season. The coefficient of variation for yield, however, exceeded 50% either in spring or in summer crop season.

b) Highly negative significant correlations were found between leaf length, leaf shape and yield, but no relationship between leaf width and leaf size with yield in spring crop season. In summer crop season, however, highly significant correlations were found among leaf length, width and size with yield.

c) No close relations were found between spring and summer crop seasons in four leaf characters, but highly significant correlation was found in yield. The latter result indicated that the genotypes were high in yield in spring crop season will be the same in summer crop season, the one what we expected.

d) Three kinds of leaf size (large, medium, and small), and three types of leaf shape (broad, intermediate, and narrow) were respectively classified based on length × width and length/width of their terminal leaflets. Aroumd 48% and 46% of germplasms (genotypes) studied had medium leaf size and intermediate leaf shape, respectively.

e) Comparison of yield among the three kinds of leaf size showed that large size ranked the highest, medium the second, and small the lowest, and their differences were statistically significant both in spring and summer crop seasons.

f) The highest yield of the three types of leaf shape came from intermadiate, and the lowest from narrow leaf shape soybeans, but no significant differences among them in spring crop season. In summer crop season, the highest yield was obtained from the broad leaf soybeans, and the lowest still from the narrow leaf soybeans. However, significant differeces was found between broad and intermediate with narrow leaf shape soybeans.

g) It is evidently that the use of large size with broad shape leaf soybean germplasms (genotypes) in breeding programme might be a feasible approach in breeding for high-yielding soybeans.

Key Words : Soybean, Germplasm, Leaf shape, Terminal leaflet, Stratified sampleing method, Simple correlation, Genetic variation, Yield.

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2. Respectively assistant breeder (soybean), assistant and assistant, Department of Agronomy, TARI, Wufung, Taichung 41301, Taiwan, Rep. of China.

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環境因子對山藥生長與產量之影響[1]

劉新裕　呂秀英　王昭月[2]　賴永昌[3]

摘要：在三處不同地區（臺中、嘉義及鳳山）栽培經本所篩選之四種產量較優之山藥品系藉由各地不同之溫度、降雨量、日照時數及土壤肥力狀況，所導致之山藥農藝性狀及產量之變化，研判環境對山藥生長與產量之影響。一般山藥的種植爲每年四月，其生長全期可分成三個階段，即初期４－５兩個月爲生根、萌芽及長葉時期，中期６－８三個月爲蔓葉快速生長時期，後期９－12四個月爲新塊莖之形成、整形、肥大及充實時期。在前兩個生長階段中，三地區之氣溫由21.1°C起逐漸上升，地上部蔓葉且於７－８月較高溫時期(27.1—29.5°C)生長最爲旺盛，惟新塊莖之生長及充實則需溫較低，三地區在其充實後期（11—12月）之溫度約爲15.6—20.2°C；在降雨量方面，鳳山地區在山藥生長初期（４月）之雨量較其他二地爲低，而在８－10月反形偏高且較爲集中，對於塊莖之形成將較爲不利。除了氣溫較高、雨量較多外，在土壤肥力方面，亦以鳳山地區較差。鳳山地區四種山藥之平均產量爲12.14t/ha，只爲臺中及嘉義之71.7%及72.5%而已。四種山藥品系中以千里達山藥之平均產量最高（17.04t/ha），雖在鳳山較不利地區之產量略差，但在較有利之嘉義及臺中兩地之產量大增，可歸類爲較理想型之山藥品系；嘉義地方種山藥之產量次之（16.85t/ha），且其變異係數幾爲其他品系之半，顯示產量較穩定；臺東地方種山藥之平均產量最低（13.54t/ha），且變異係數最高，顯示較不理想且不穩定；巴西山藥在鳳山之產量（20.29t/ha），顯著高於其他品系，在其他地區則表現不佳，應屬於特別適合鳳山之山藥品系。

關鍵詞：山藥、環境因子、生長、產量。

環境決定作物之生產行爲，由於各種作物對不同環境因素之反應很不一致，因此可將作物區分成三類：低敏感型、一般型及高敏感型。低敏感型之作物對不同環境反應之穩定性較高，高敏感型作物在不同環境下之穩定性較低；理想之作物品（種）系應屬在不利環境下之敏感度較低，適足以維持一定之產量，而在合適環境下之敏感度甚高，其產量預期將高[12]。本省位於亞洲大陸與太平洋交接之低緯地帶，氣候高溫多濕，作物種類豐富，加以地形複雜，將加重環境中氣象因素對作物之影響程度。

山藥爲薯蕷科（Dioscoreaceae）薯蕷屬（Dioscorea）之蔓性多年生植物，本所特用作物研究室致力於蒐集及篩選優良山藥品系，其中千里達山藥、巴西山藥、嘉義地方種及臺東地方種山藥，爲四種產量表現優異之白肉山藥品系，此四者在植物分類上都屬於短形塊莖之大薯（*D. alata* L.），只在植株外形及地下塊莖形態上略有差異[6]，另外尙有長條型塊莖之山藥，如基隆山藥（*D. japonica* Thunb. var. *pseudojaponica* Yamam.），本省瑞芳地區亦有栽培。

由最近三年本所在臺中、嘉義及高屏地區之山藥栽培試驗之結果可知，短形類山藥之生長勢及產量皆以高屏地區較差，初步研判其原因，可能爲其氣象因子（溫度、降雨量及日照時數）、或土壤

1. 臺灣省農業試驗所　研究報告第 1536 號，本試驗承蒙行政院農業委員會補助部分經費（78食報計畫07－２），及本所鳳山園藝試驗分所曾紹均先生之協助，謹致謝意。
2. 本所農藝系研究員、副研究員、助理。臺灣省　臺中縣　霧峰鄉。
3. 本所嘉義分所農藝系助理。臺灣省　嘉義市。

差異，或人爲管理之單一或綜合影響所致。本文之目的在探討於三處不同地區栽培上述四種山藥品系，將藉由各地相異之環境因素對山藥產量之變化關係，研判各種環境因子對山藥之影響程度，以提供將來推廣山藥生產之參考。

材料與方法

1. 材料：四種白肉山藥品系：千里達山藥（Coconut-Lisbon）、巴西山藥（Brazilien yam）、嘉義地方種山藥（Chiayi local yam）及臺東地方種山藥（Taitung local yam）。

2. 方法：不同地區之山藥栽培試驗於77年4月進行，於臺中本所農場、嘉義及鳳山兩分所種植上述四種山藥品系，田間設計爲RCBD，重複三次，三行植，行株距100×30cm，小區面積12m²。種薯每粒重量爲70g，每穴植一粒，皮面向上，種後覆土約3cm。肥料用量爲N：P_2O_5：K_2O＝90：60：90kg/ha 及牛糞每0.1ha爲1,000kg，其中全量之磷、鉀肥與牛糞於整地時混施土中，氮肥則均分三次施用，即4月整地時、6月莖葉伸長期及8月新薯形成期，施追肥時宜先將蔓葉翻到畦上，且沿畦側開條溝施肥，其後覆土並適量灌水。由於山藥初期生長較慢，宜適時除草，並視需要防治病蟲害。取樣調查於萌芽後每月一次，取邊行各3株供作調查材料，於12月採收時取中行植株作產量調查材料。調查項目爲：株高、全株重、分蘗數、莖徑、葉數、地上部重、地下部重、根長、新塊莖數及新塊莖重等。

氣象因子分爲溫度、降雨量及日照時數三項，臺中本所氣象資料取自本所氣象站，位於霧峰本所農場內，嘉義及鳳山兩分所之氣象資料取自中央氣象局主編之農業氣象旬報。鳳山地區之日照資料缺如，將採計高雄之資料供作參考。三處栽培地區之土壤取樣分析項目爲：pH值、土壤質地、有機質、有效P及有效K量。

結　果

一般山藥的種植時期爲每年四月[8]，於歷經8個月生長時期後，當莖葉等地上部位因秋冬來臨溫度下降而枯黃凋萎時，即爲其採收時期。本試驗四種山藥品系之種植及採收時期亦同此，圖1顯示臺中地區四品系山藥植株各部位在全生育時期的平均鮮重變化情形，其中全株重代表著地上部及地下部鮮重之消長關係，地上部重爲其葉及蔓之鮮重變化，地下部重於扣除小比率之根重後，主爲其母塊莖及新塊莖鮮重之增減關係。以母塊莖而言，其重量隨生育時期而遞減，所損失之重量最主要用於提供植株初期萌芽及生根之用；以新生塊莖而言，由於新塊莖形成與發育在山藥之生育後期，較低之溫度似較有利於塊莖養份之貯存，所以自每年八月起其鮮重之增加程度與當時之溫度有密切關係，由圖1可知，新塊莖之增重幅度於11—12月份較低溫時期明顯快於其他時期；地下部之鮮重曲線，於9月份前呈緩慢下降，略同於母塊莖曲線，於其後則相似於新塊莖曲線；地上部蔓及葉之生長於7－8月間達到最旺盛狀態，於10月以後由於溫度逐漸下降而漸趨枯萎，鮮重即形下降；全株重之影響因素在9月以前以地上部鮮重之作用最大，九月以後應以新生塊莖重之影響最大。

由圖1可區分山藥全期生長成爲三個階段：4－5兩個月爲生根及萌芽長葉時期，6－8三個月爲蔓葉快速生長時期，9－12四個月爲新塊莖之形成、整形、肥大及充實時期。

由圖2可知本次試驗三處山藥栽培地區之溫度變化情形，於4－5月時三地點之溫度介於21.1°—28.6°C間，6－8月之溫度介於27.3—29.5°C間，9－12月介於15.6—28.4°C間。鳳山地區之溫度曲線除了7－8月略低於臺中地區外，其他月份之溫度明顯高出其他二地，鳳山地區4－12之平均溫度爲26.19°C，依次高出臺中及嘉義二地區1.4°C及2.1°C，尤其9－12月之平均溫度依次各高出臺中及嘉義達1.7°C及3.0°C，於山藥生育後期若氣溫偏高，將對該地山藥塊莖之生長與發育較爲不利。

由圖3可知三處山藥栽培地點田間降雨量變化情形，於4－5月山藥之生長初期，三處地點之雨

量介於 100—181㎜ 之間；於 6 — 8 月山藥之生長中期，除了臺中地區 6 月之降雨量偏低外，一般均高於初期者，尤以 7 — 8 月間三處之雨量最高，其中以鳳山地區之756㎜ 爲最，最低之臺中亦高達279㎜。自 9 月開始到12月底三地區之降雨量遽降，尤以10—12月塊莖之充實中期及後期爲然，此時期最高雨量爲26㎜（鳳山），最低只有1.8㎜（嘉義），塊莖產量最高之臺中地區之平均雨量亦只達10.3㎜ 而已，產量次之之嘉義地區只有5.9㎜，產量較差之鳳山爲15.31㎜。

由圖 4 可知三處山藥栽培地點全年有效日照時數變化情形，臺中地區於 4 — 8 月之日照時數逐漸增加，於 9 月份時略減，但10—12月之日照時數均維持在 7 小時以上，較其他二地高出不少；嘉義地區由 4 月起增率頗大，於 6 月時達到高峰，之後逐漸減少，於10月時只爲4.61小時，雖其後又有上升趨勢，但皆不及臺中者；因爲鳳山地區之日照數據缺如，暫以其鄰近之高雄地區者作爲參考，其日照時數由 4 月起上升，於 7 月時達到高峰，之後下降頗速，於10月時只剩4.58小時，其後亦有上升趨勢，惟仍不及其他二地者。

比較山藥三處栽培地點之土壤分析結果可知（表 1），三處地點之土壤質地都是壤土，pH值以臺中之5.1較偏酸性，嘉義及鳳山兩地都是6.8，較趨於中性；就有機質、有效 P 及有效 K 量而言，都以嘉義地區之含量較高，鳳山地區偏低，臺中地區除了有效 P 含量最低外，有機質及有效 K 之含量介於嘉義及鳳山之間。四種山藥在此三處地區所生產之塊莖平均公頃產量以臺中地區之16.93t/ha最高，嘉義次之，鳳山之產量顯著偏低，爲12.14t/ha，依次只爲臺中及嘉義之71.7%及72.5%而已。

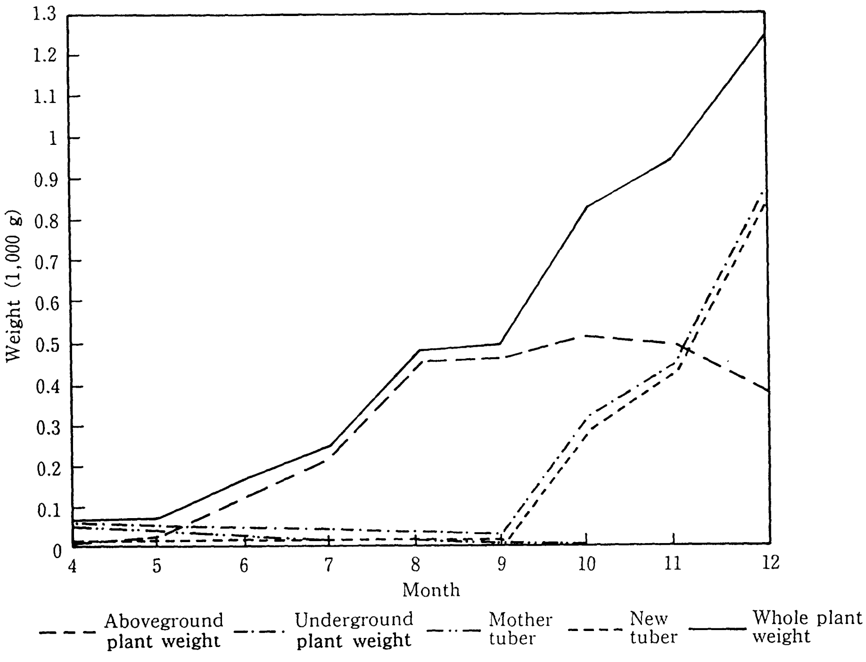

圖 1. 山藥植株重要部位之生長曲線

Fig 1. Changes of fresh weight in the different plant parts of yam during growth period at Taichung in 1988.

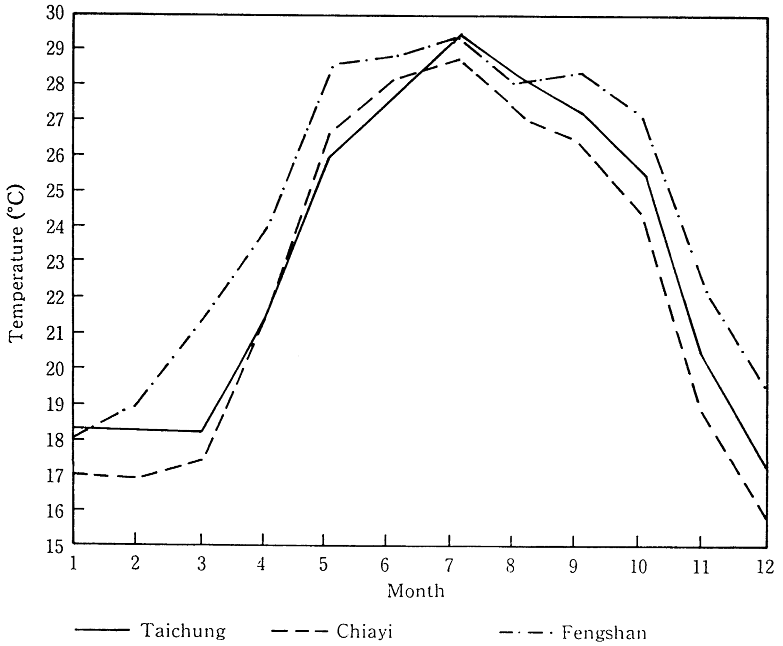

圖 2. 不同山藥栽培地區之溫度變化情形

Fig 2. Annual changes of temperature (°C) at three experimental locations in 1988.

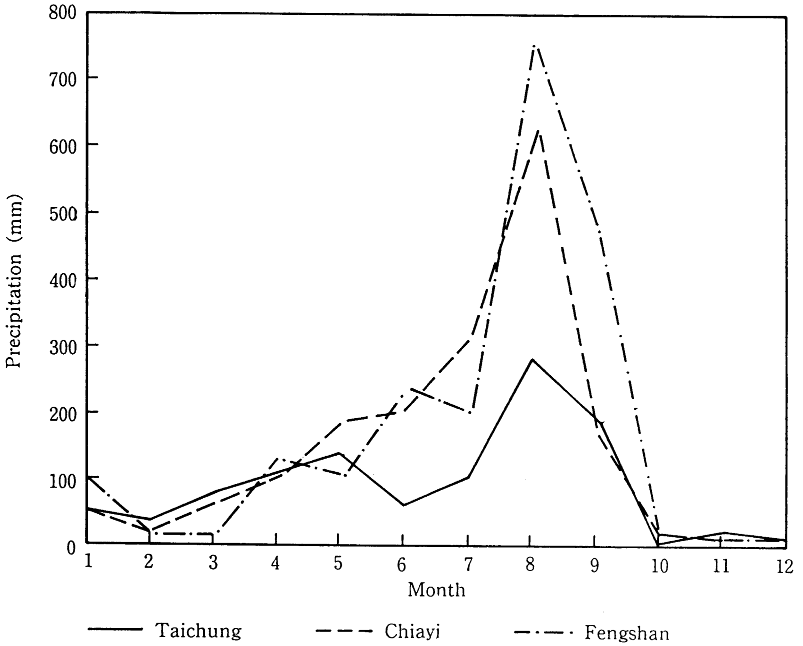

圖 3. 三處山藥栽培地區之雨量變化情形

Fig 3. Annual changes of precipitation (mm) at three experimental locations in 1988.

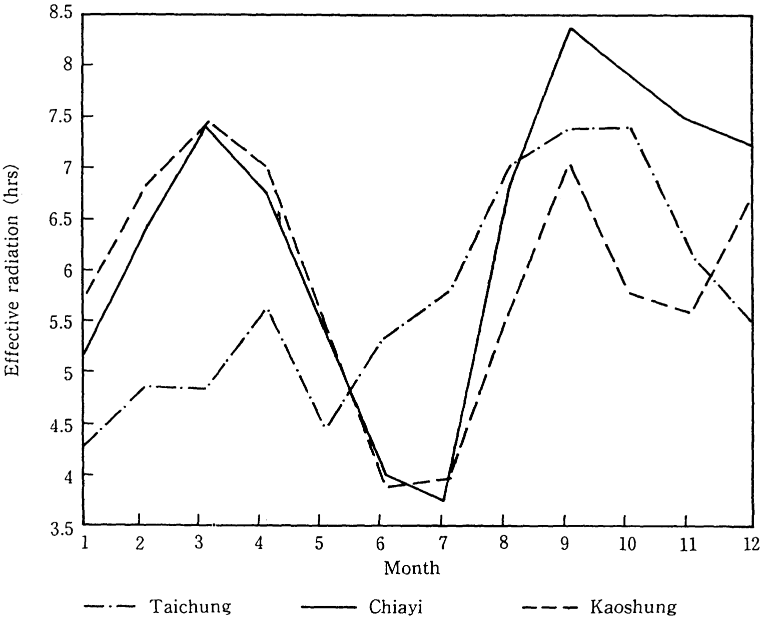

圖 4. 三處山藥栽培地區之日照時數曲線圖

Fig 4. Annual changes of effective radiation (hr) at three experimental locations in 1988.

表 1. 山藥四品系栽培於三處地區之土壤分析結果及平均產量

Table 1. Soil analysis and tuber yield averaged over four yam lines cultivated at three experimental locations in 1988.

Location	pH	Soil texture	Sand (%)	Clay (%)	Silt (%)	Organic matter (%)	Effective P (P_2O_5 kg/ha)	Effective K (K_2O kg/ha)	Tuber yield (t/ha)
Taichung	5.1	L	40.9	14.0	45.1	1.87	123.2	307.3	16.93[a*]
Chiayi	6.8	L	52.9	9.0	38.1	2.13	256.9	394.6	16.74[a]
Fengshan	6.8	L	40.9	13.0	46.1	1.14	133.8	162.7	12.14[b]

* Means followed by the same letter within the column of tuber yield are not significantly different at 5 % level by LSD test.

山藥四品系在三處不同地點之性狀表現結果列於表 2 ，臺東地方種山藥之株高平均值爲四種山藥之冠，其他三品系之差異則不顯著。就變異係數而言，以巴西山藥最小，而以嘉義地方種最大，根據變異係數與穩定性之相互關係，顯示巴西山藥之株高不受環境所影響[10.11]。在全株重方面則以嘉義地方種最高，每株平均達1.2kg以上，且其變異係數最小，只約爲臺東地方種之¼左右，由此可知其在三處栽培地點之全株重表現最好且較爲穩定。參試山藥四品系分蘗特性間之差異不顯著，惟其變異係數都超過35%，顯示此項特性在不同栽培地點之差異甚大。在莖徑方面，千里達山藥與巴西山藥兩者均遠不如嘉義及臺東兩個地方種，惟其變異係數亦較小，顯示在各地區之穩定性較高。在葉數及根長兩性狀方面，四種山藥品系間之差異並不顯著，惟千里達山藥之表現似較爲穩定，因其變異係數最小。嘉義地方種及千里達兩品系之塊莖及根之鮮重亦最大，是其優點，惟因鮮重之 cv 值稍高，顯示地區間仍存有頗大之變異性。嘉義地方種單株塊莖鮮重雖略低於千里達山藥，但差異未達顯著水準，由於其變異係數最小，就地區間單株產量及穩定性而言，應爲所有參試品系之最佳者。

表 2． 山藥四品系在三處不同地點之性狀表現

Table 2. Parameters measured in the tested yam lines averaged over three experimental locations in 1988.

Line	Statistical analysis	Plant height (cm)	Plant weight (g)	Tillers (no/pl)	Stem diameter (cm/pl)	Leaves (no/pl)	Tuber & root (g/pl)	Root length (cm/pl)	New formed tuber (no/pl)	New tuber weight (g/pl)
Coconut-Lisbon	MEAN	398.80^{b*}	921.90^{b}	4.20^{a}	0.57^{b}	372.80^{a}	670.70^{a}	33.40^{a}	4.20^{a}	612.80^{a}
	CV (%)	20.66	39.07	45.24	10.53	16.82	51.11	6.89	30.95	46.10
Brazilien yam	MEAN	392.00^{b}	867.10^{b}	3.40^{a}	0.58^{b}	322.00^{a}	496.80^{b}	33.20^{a}	2.80^{c}	491.00^{b}
	CV (%)	11.05	27.92	52.94	13.79	41.68	47.81	13.86	57.14	48.07
Chiayi local yam	MEAN	397.80^{b}	1,212.80^{a}	3.90^{a}	0.68^{a}	347.40^{a}	698.10^{a}	31.30^{a}	3.70^{b}	606.10^{a}
	CV (%)	21.59	10.74	35.90	23.53	56.16	33.63	9.17	45.95	24.60
Taitung local yam	MEAN	480.10^{a}	868.40^{b}	3.60^{a}	0.67^{a}	373.70^{a}	545.60^{b}	36.30^{a}	3.30^{b}	487.20^{b}
	CV (%)	14.83	42.79	44.44	25.37	36.53	64.90	38.84	21.21	53.94

* Means followed by the same letter within each column are not significantly different at 5 % level by LSD test.

表 3 指出四種山藥品系在三處地點之產量表現情形，千里達山藥與臺東地方種兩者在臺中之產量最高，產量差異不顯著，惟都明顯高於嘉義地方種及巴西山藥，千里達之產量稍高，爲22.7t/ha，依次爲巴西山藥及嘉義地方種之315%及139%；千里達山藥在嘉義地區之產量略差於嘉義地方種山藥，惟差異未達顯著水準，其產量（20.4t/ha）仍依次爲巴西山藥及臺東種山藥之151%及172%；千里達山藥及臺東地方種山藥在鳳山地區之產量表現均欠佳，而以巴西山藥之表現最好，嘉義地方種次之，千里達山藥之產量（8.1t/ha）依次只約爲巴西山藥及嘉義種山藥之40%及62%而已。綜合比較山藥四品系之產量可知，千里達山藥以17.0t/ha居先，其次爲嘉義地方種之16.9t/ha，其他二品系之產量偏低，巴西山藥爲13.7t/ha，臺東種山藥爲13.5t/ha，四品系產量間之差異顯著。千里達山藥之產量雖然最高，惟其 cv 值高達46.1%，遠不如嘉義種山藥之產量穩定，其他二品系之 cv 值更高，顯示應愼選栽培地點，否則各地之栽培結果將有很大之產量差異。由表 3 可知，千里達山藥較適於臺中至嘉義一帶栽培，巴西山藥較宜於鳳山栽培，臺東種山藥若於臺中地區栽培，其產量可望較高，嘉義種山藥各地產量之 cv 值最低，於不同地區栽培時之產量可望較爲穩定，惟仍以嘉義地區栽培較爲理想。

表 3． 山藥四品系在三處不同地點之產量差異比較

Table 3. Comparison on yield (t/ha) of four yam lines cultivated at three experimental locations in 1988.

Location	Yield (t/ha)			
	Coconut-Lisbon yam	Brazilien yam	Chiayi local yam	Taitung local yam
Taichung	22.65^{a*}	7.18^{c}	16.35^{b}	21.55^{a}
Chiayi	20.38^{a}	13.48^{b}	21.22^{a}	11.86^{b}
Fengshan	8.06^{c}	20.29^{a}	12.97^{b}	7.23^{c}
MEAN	17.04^{a}	13.65^{c}	16.85^{b}	13.54^{d}
CV (%)	46.07	48.06	24.63	53.99

* Means followed by the same letter within each row are not significantly different at 5% level by LSD test.

表 4 進一步指出三處不同栽培環境與山藥產量之關係，臺中與嘉義兩區之環境離差依次爲1.66及

1.47，兩者同爲正值且數值接近，表示兩地有類似之環境條件[12]，均適宜栽培山藥，惟就有利程度而言，則以臺中較佳，兩地間產量之差異顯著；鳳山地區之環境離差爲負值，且產量只達12.14t/ha，顯著差於其他二處地區，表示爲一不利地區。理想之山藥品種應爲在環境惡劣時不致表現太差，而環境改善時，其產量將可大增。依據圖5之結果可知，千里達山藥應爲較理想型山藥品系，雖在鳳山較不利地區之產量表現略差，但在較有利之嘉義及臺中兩地，其產量表現有大幅提升之趨勢。臺東地方種山藥在臺中地區之產量亦呈大幅提升之現象，惟在嘉義地區之提升程度不如其他山藥品系，且在鳳山的產量偏低，以致其產量 cv 值（53.99）高居參試山藥品系之冠（表3）。嘉義地方種產量之 cv 值遠較其他品種爲小，顯示其產量表現較爲穩定，雖然在不利之鳳山地區表現不差，但在更有利之臺中地區之表現不如次佳之嘉義地區，所以應屬於較適合於嘉義地區栽培之山藥品種，巴西山藥在鳳山不利環境下之表現最佳，但於嘉義及臺中有利環境下反而表現最差，應屬於特別適合鳳山地區栽培之品系，若在臺中種植巴西山藥時，可能須有其他栽培技術配合方可。

表4. 環境對不同地區山藥產量之影響程度

Table 4. Environmental effect on yield of yam averaged over four lines cultivated at three experimental locations in 1988.

Location	Environmental effect	
	Yield (t/ha)	Deviation
Taichung	16.93[a*]	1.66
Chiayi	16.74[b]	1.47
Fengshan	12.14[c]	− 3.13

* Means followed by the same letter within the column are not significantly different at 5% level by LSD test. Mean yield calculated from data in Table 3.

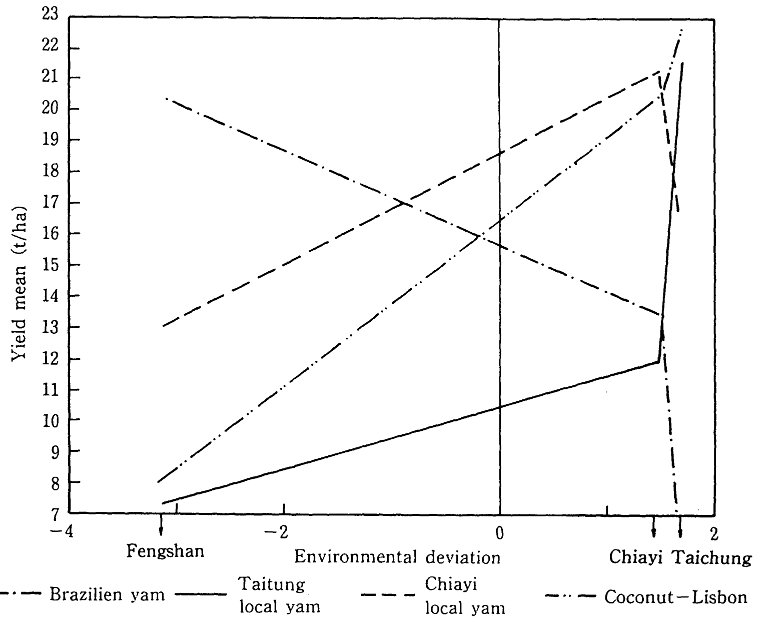

圖5. 四種山藥品系在三處栽培地點之產量與環境離差關係

Fig 5. Relation of environmental deviation and yield mean of four yam lines cultivated at three experimental locations in 1988.

討　論

本文論及之環境因素，只限於氣象因子及土壤肥力二項。爲瞭解氣候對山藥生育之影響，本試驗採取在三處不同地區栽培經本所篩選之四種產量較優之山藥品系，擬藉由不同地區之氣候表現所導致之山藥性狀及產量之變化，研判氣候之影響程度。類似之研究方式，尙有(1)蒐集同地區歷年（至少十年）作物產量與氣候資料，藉由複迴歸分析等統計方法，建立數學模式以研判之，及(2)於田間利用人爲方式來改變局地農田微氣象環境之改變，調查其對作物生育及產量之影響[6]；前項須時較長，且資料之均一性，如施肥量及其他管理方式之是否一致，都應慮及，而後者須藉助較爲精密之微氣象儀器，非本試驗之設備所能及。

溫度是影響農業發展之主要環境因子之一，以其強度（溫度數値高低）、持續時間（積溫大小）和變化情形（周期性及非周期性）三個變數來決定影響程度之大小[3]。有關影響作物生長的溫度因子，則又包括空氣溫度、土壤溫度及作物本身體溫等三項，前二項屬於外在溫度環境，作物體溫則屬於內在溫度環境範圍，而土壤溫度對作物初期之影響尤大，舉凡種子或種薯之發芽、幼苗之生長、根部之發育等均有影響力[3,9]，若能於作物栽培期間增高土壤溫度，將對作物之生長與發育很有幫助。於本試驗山藥全期生長之三個階段中，前二階段之空氣溫度呈逐步上升現象，此對於土壤溫度之提升及對山藥地上部蔓葉之生長與發育都有正面促進作用，惟過高之土溫亦有負面之影響，因土溫增高會加速有機物之分解及有機氮之礦化作用，土中微生物也會因溫度變遷而有所更替。此外，藉由本所三年田間生長觀察結果以比較短形類山藥之生長優劣如下，臺中及嘉義二地區山藥之生長情形較鳳山爲優，若暫時不考慮其他因素，而只參考本年內臺中及嘉義 4 — 5 月之溫度，將可大略了解山藥初期生長發育之適合溫度爲21—27°C之間；於 6 — 8 月時爲山藥蔓及葉主要生長階段，其中尤以 7 — 8 月爲其蔓及葉生長最旺盛時期，6 — 8 月臺中及嘉義之溫度27.3—29.5°C，或可以爲是山藥蔓葉生長之一般溫度；9 —12月最主要爲山藥新塊莖生長及充實時期，由於臺中及嘉義地區山藥的產量遠較鳳山爲佳，藉由嘉義及臺中兩地之溫度數據可知，山藥塊莖形成初期（9 —10月）較適合溫度或爲24.3—27.4°C，中期（10—11月）爲18.6—25.7°C，後期（11—12月）爲15.6—20.2°C，此較適溫度呈現逐漸下降趨勢。有關山藥生長各期之適溫問題，值得更深入去了解與探討。

超過作物生育最適溫度之高溫可導致作物之生育受阻及產量與品質之損失[5]，若乾旱伴隨高溫而生，或高溫時之降雨量分佈不均或持續較久，則影響之程度可能更大[4]。鳳山地區之溫度一般高於嘉義及臺中地區，而其降雨量之分佈亦較不平均，於山藥生長初期之 5 月之雨量較其他地區爲少，於生長中期 6 — 8 月之平均雨量則最高，幾近400mm，於塊莖形成期之 9 月之雨量更高達465mm，依次爲嘉義及臺中之2.6及2.4倍，由於降雨量高且較集中，將對山藥之生理作用、施肥效應及產量與品質造成負面影響[7]，如以甘藷爲例，淹水降低甘藷塊根之大小與數目，且生長45天之甘藷於淹水後，可恢復正常之生長，而生長100天者，則無此反應[1,2]。高溫及乾旱對於作物之影響不一，其中品種間耐熱性之差異，可能亦表現在參試之四種山藥品系，巴西山藥於鳳山地區之表現特優，或許即具有較大之耐熱能力。相關品種之耐熱性試驗，值得將來進行深入之探討與比較。此外，決定作物各種病蟲害的氣象因素很多，包括土壤溫度、土壤濕度、通風及露水之多寡等[7]，三處栽培地區山藥病蟲害之發生程度不大，除了略見炭疽病外，鳳山地區之蟲害率則稍高，此應與其較高溫度及降雨量有關，亦將影響該地之山藥產量。

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Effect of Environmental Factors on the Growth and Yield of Yam (*Dioscorea alata* L.)[1]

S. Y. Liu, H. Y. Lu, C. Y. Wang[2], Y. C. Lai[3]

Summary

Four yam lines having high yielding potential were tested for their growth and yield responses to different climate and soil conditions at three cultivation locations, i.e., Taichung, Chiayi and Fengshan. The purpose of this study was to evaluate some suitable environmental factors for yam production and to select an ideal line of yam in favour for all possible cultivation locations.

Based on the results of agronomic characteristics and yield performances, suitable temperature range for growth and development of roots, runners and leaves was between 21.1°C and 29.5°C, and for development and enlargement of new tubers was between 15.6 °C and 20.2°C. Comparing the climate and soil conditions at three yam cultivation locations, Fengshan area was less advantageous than Taichung and Chiayi areas, due to the higher temperature throughout all growth stages of yam, the concentrated and large amount of rainfall in the period from August to October, and the least quantities of organic matter and effective K in soil. The averaged tuber yield of 12.14 t/ha at Fengshan was only 71.7% and 72.5% of that at Taichung and Chiayi, respectively. Experimental results indicated that Taichung area was the most suitable place for the cultivation and production of yam.

Among the four yam lines, Coconut-Lisbon can be recommended as an ideal line of yam. Although it produced less at Fengshan area, its mean yield was significantly more superior than the other lines under better environmental conditions such as Taichung and Chiayi areas. Chiayi local yam was the most stable one (cv=24.63), though its mean yield was not the highest among the lines. On the other hand, Taitung local yam was the most unstable line of yam (cv=53.99). Yield of Brazilien yam was significantly higher at Fengshan area than at two other locations. It might be the only line that can be suggested for that area.

Key Words : Yam (*Dioscorea alata* L.), Environmental factors, Growth, Yield.

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2. Senior agronomist, statistician, and assistant, respectively. Department of Agronomy, TARI, Wufeng, Taichung Hsien, Taiwan 41301, ROC.
3. Assistant, Chiayi Agricultural Experiment Station, TARI.

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促進葡萄插枝上花穗發育之研究[1]

王 為 一[2]　　Alain Bouquet[3]

摘要：本試驗利用插枝基部加熱法、設定萌芽順序法與NAA處理等，促使葡萄插穗發根，並配合幼葉及頂梢摘除等工作，防止流花，並促進結果。結果發現：插枝基部加熱法與設定萌芽順序法，均可在目的芽萌芽前促使新根正常生長，但僅插枝基部加熱法，可促花穗發育，而結果穗。

關鍵詞：設定萌芽順序、結果扦苗、花穗。

無子葡萄因不需剝皮、吐子將成爲未來鮮食葡萄領導品種，爲不可避免的趨勢，本所有鑑於此，於民國73年起進行無子葡萄選育工作。然在選種過程中，卻發現所收集到的多數無子品種，因新梢帶花率極低，無推廣的價值，而開始進行育種工作；然又因品種間花期不一及降雨的阻礙等，使雜交效率低且不穩定。再加上本省積熱高，果實成熟快，營養生長旺盛，養分易被新梢消耗，種子在沒有足夠的時間和充足的養分生長下，自是發育不全。更因本所果園易遭外人侵入，爲避免雜交果實失竊，必需提早採收，萌芽率更低，育種效果益發不彰。爲克服上項困擾，著者於民國75年10月在國科會及中法基金的經費補助下，前往法國 Montpellier 葡萄中心，進行6個月的葡萄育種之研究。

傳統上，無子葡萄育成，是以有子葡萄爲母本，以無子葡萄爲父本，進行雜交，待種子收穫後，再由後裔中選拔(11)。但因無子特性爲 2 ～ 3 對隱性基因所控制，因此平均僅有13%的後裔具無子的可能(12)；再由這些無子後裔選出良好的選系，所需的人力、物力要較有子品種的育成高出八倍。因此 Dr. Bouquet 試圖經由培養無子葡萄花藥，促產生體細胞變異的方法，進行育種，期藉此選出適應法國風土和栽培系統的變種（mutant），以縮短無子葡萄育種之年限，而進行改善硬木插上花穗發育之研究。希望藉此可終年培養貯藏在冷藏庫中的插枝，獲得花藥，以方便花藥培養工作。

由於盆栽結果葡萄是一種非常好的花粉供給者（Pollen donner），果實又可在溫室內得到良好的保護，使種子充分成熟，而具有較高的萌芽率(16)，又可在室內進行操作，不懼風雨與外來的侵害，大幅提昇育種效果，因此本試驗符合本所育種需要。希藉葡萄盆栽建立本所新的葡萄育種制度，大幅提昇育種效果，以盡速達成無子葡萄育種之目的。

材料與方法

本試驗以 Beauty Seedless 與 Sultana 無子葡萄爲試驗材料，取自法國 Montpellier 葡萄研究中心（Centre de recherches de Montpellier, 北緯44，東經3.8度）所屬農場，材料業已經過足夠的冬季低溫打破休眠，並儲藏在0°C下。枝條取出後，剪成25～30公分，含3芽之插枝，經24小時溫水（25°C）浸泡後，分別以下列方式處理：(A)粗橡皮筋束縛第二芽，(B)以10，100，500ppm NAA倒浸插枝三分之二1小時，(C)對照未處理。再扦插在含珍珠石：粗河砂＝1 ：1之小泥炭盆中。然後

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2. 臺灣省農業試驗所園藝系助理研究員。臺灣省　臺中縣　霧峰鄉。
3. Rechercheur. Centre de recherches de Montpellier, Station de recherches viticoles. INRA. France.

將材料分爲兩組，一組直接移入暖房（25～27°C），使萌芽；另一組則先移入水苔介質內設有加熱板的封閉塑膠盒中，根溫維持在25°C左右，再移入 4 °C冷藏庫 6 星期，使芽體維持休眠狀態，促根先生長，使其成爲具根扦插苗（Prerooted cutting），再移入暖房。萌芽後，盡早去除幼葉，直到小花穗出現，再去頂[5]。以粗橡皮筋束縛第二芽處理組，待第一芽萌芽至小花分離後（此時根已發育良好），再摘取花穗及第二芽上之橡皮筋，使第二芽萌發。試驗中，分別記錄含花穗株數與達小花分離期株數。

結　果

在法國絕大多數的葡萄均採短梢剪定，即僅留兩芽就可得到足夠的果實，換句話說：在法國的氣候與土壤等條件下，絕大部分的葡萄經濟品種，其基部兩芽，甚至期部隱芽均具有良好的結實潛能。然由表一可以看出，Beauty Seedless 和 Sultana 無子葡萄，既使是較高節位的芽體，其所萌新枝上，含花穗率亦甚低，顯示該二品種在法國因芽體結實潛能低下，而必須在冬季採特長梢剪定和春季以人工除去半數以上未結果的營養枝，方可生產。這也是爲何在大面積機械栽培的法國無法直接利用該等品種，而需自行育種的原因。

表一：設定第二芽後萌處理對插枝上花穗發育之影響

Table 1. Effect of assigning budding order on the development of inflorescence on cutting.

品種 Varieties	處理方法 Treatment	芽序 Node number	株數 No. plant	花穗數 No. inflorescence	小花分離株數 No. in stage of floret seperation
Beauty Seedless	對照 CK		7	4	4
	萌芽設定 Assigning budding order	第一芽 1 node	8	5	4
		第二芽 2 node	8	2*	0
Sultana	對照 CK		7	2	1
	萌芽設定 Assigning budding order	第一芽 1 node	8	3	1
		第二芽 2 node	8	0*	0

*：幾乎所有芽體均不能正常萌芽生長。
Almost all the node burst abnormally.

表二：不同濃度 NAA 處理對插枝上花穗發育之影響

Table 2. The effect of different concentration of NAA on the development of inflorescence on cutting.

品種 Varieties	處理濃度 Concentration	株數 No. plant	花穗數 No. inflorescence	小花分離株數 No. in stage of floret seperation
Beauty Seedless	對照 CK	10	6	5
	10 ppm	10	5	4
	100 ppm	10	5	0
	500 ppm	10	*	*
Sultana	對照 CK	10	4	1
	10 ppm	10	3	1
	100 ppm	10	3	0
	500 ppm	10	*	*

*：插枝頂端產生根群，因而廢棄。
The cuttings were discarded because of root formation on the top of cutting.

對照組及設定萌芽順序組之第一芽，其花穗發育尚稱良好，但在摘取設定萌芽順序組第一芽之花穗後，其根雖已生長良好，但第二芽所萌之花穗卻無法發育，甚至部分新梢無法抽出及展葉。品種間以 Beauty Seedless 芽體分化與花穗發育較佳。而 NAA (Naphthaleneacetamide) 處理隨所用濃度而異，在 500ppm 時會造成藥害，使頂部發根，在 100ppm 時，亦會造成頂部腫脹、破裂及所萌新葉白化，但在 10ppm 時，則無此現象，然對花穗的發育亦無明顯幫助。至於插技基部加熱法所培養的苗木，因培育時，培養箱中溼度失控，造成插穗基部黑變，而告失敗；唯隨後所補行的相同試驗中，獲得成功的果實（圖二）。

討　論

Beauty Seedless 及 Sultana (Syn. Thompson Seedless) 無子葡萄，不論在本省或法國，均屬不易開花結果的品種，必需離枝條基部較遠的芽體，才具有結實潛能。在法國，由於需採特長梢剪定，才能進行生產，因此栽培受限。而在本省，即使採用特長梢剪定，亦未必能開花，影響本所無子葡萄育種工作甚鉅。倘若能充分利用冬季修剪下，離枝條基部較遠，帶結實潛力芽體的枝條，進行扦插，促使開花，則對育種工作幫助甚大。

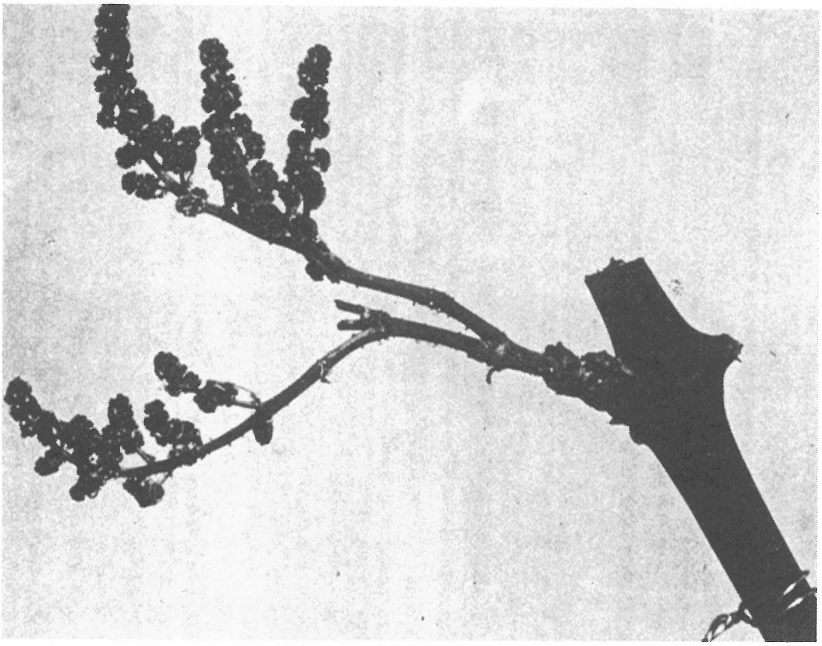
然凡與結實有關的果樹研究，都面臨了因其具有龐大的體積，而不能或不易移入可控制的環境下，加以探討的困境；因此許多值得研究的項目或可利用的技巧，均難以在果樹學上得到應證。爲了克服上項困擾，如何開發有效的結果果樹盆栽技術，爲近年來研究人員努力的目標[16]。

一般而言，葡萄插枝萌芽後，其芽內所含的花穗原始體，並不能因新梢的生長而跟著發育；相反的，會因根、頂梢和新葉對養分的競爭，而停止發育，終至枯萎。

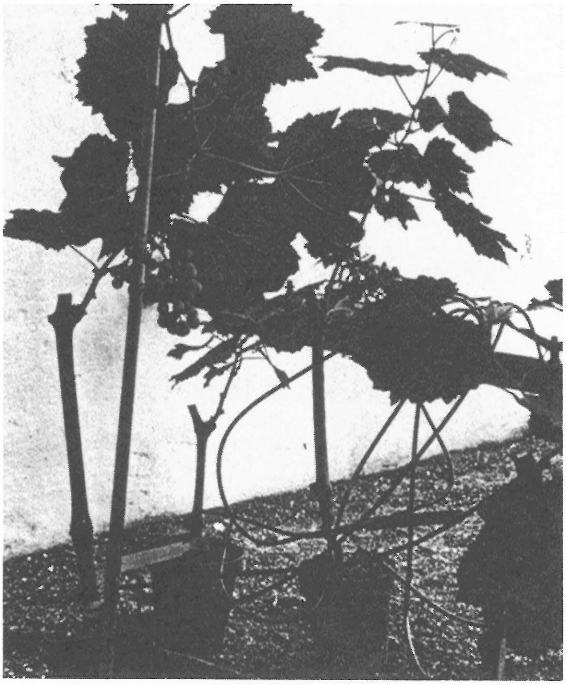
Alexander 氏等利用 Sultana 葡萄高壓苗，首開葡萄盆栽化之先河[2]。隨後又以已完成芽體分化的枝條進行半綠技插，稍改善高壓苗帶果穗率過低的缺點[1]。Janick 氏更進一步利用0.1～0.3% IBA 改善綠技插扦插和移植的時間，使 Aurore 葡萄半綠枝插在扦插後40天，即可移植到露地培養，節省原所需的溫室設備及費用[3]。然此種方法仍需要龐大的人力，噴霧設備及超過 8 個月以上的時間，方能確定所培育的苗木是否具有結實能力，以致需維持龐大的苗木數量，方能在來年萌芽後選出所需數量的試株。雖然 Robitaille 氏等利用0.1～0.3% IBA (Indolebutyric acid) 成功的插活了 Couderc 1613（一種可結果的砧木選系）剛著果的結果枝，可在短時間得到結果葡萄盆栽[9]；然而此種方法所繁殖成功的盆栽，果穗均貼近盆土，易受水分及病菌侵害，缺乏研究利用價值。

Srinivasan 氏等利用10～20 ul，50～200 uM 的 PBA (6—(benzylamino)—9—(2—tetrahydropyranyl)—9H—purine) 重覆處理已除去頂梢、幼葉及側芽的 Muscat of Alexandria 葡萄新生卷鬚（＞7 mm），可使卷鬚分化爲花穗，並開花結果。雖然 PBA 可促大部分的葡萄品種或實生苗的卷鬚轉爲花穗，但並非每個品種均可開花結果。其中 Muscat of Alexandria 是可高度結果的品種，而 Sultana 卻不能結果[15]。因而可知，花穗的發育，是一種需求 Cytokinin 的過程。而花穗的流花，則是 Cytokinin 不足或內生何爾蒙不平衡，以至養分競爭失敗的結果。而品種間，因遺傳質的不同，會有顯著的差異。

Mullins 氏利用早期去除幼葉，以節省養分供給花穗發育的技術，促使6公分長的 Carbernet Sauvignon 葡萄單芽插苗著果[6]。並試圖以 PBA 和 BAP (6—benzylaminopurine) 改善幼嫩花穗的發育[5]。然仍以低溫（4°C）抑制上段芽體萌發，以高溫（25°C）刺激插枝基部先發根，再移入暖房促使萌芽，稱爲 pre-rooted cutting 的方法，處理 6 節長的 Carbernet Sauvignon Grenache 葡萄插枝，所改進花穗發育情形最佳，雖然大部分的花穗仍在小花分離期(flower separation)死亡，但卻有少數植株能開花[5]，然若在二次梢生長到4～6片葉片後，再摘心、除側芽，則可改善其結果的能力[16]。唯此方法在處理上仍有相當困難，諸如需有冷藏室配合，且新根的發育頗難控制整



圖一：硬木插上花穗發育至小花分離期。
Fig. 1. Floret seperation on cutting.



圖二：Beauty Seedless 硬木插苗結果之情形。
Fig. 2. Fruiting cutting of Beauty Seedless.

齊等等；然一般而言，葡萄插枝均先萌芽，後長根，若利用此一既存特性，預先設定某些芽體後萌發，則該等芽體在萌發時，插枝已有相當多的新根群，應不至有 Cytokinin 缺乏的問題。

本試驗結果發現，萌芽後，立即去除新葉，有利於花穗之發育，然發育至小花分離期後，小花並無能力開花，相反的會萎縮流失；且在設定萌芽順序組中，新根已在第一芽萌芽後開始發育，到摘取第一芽時（花穗取作花藥培養之材料），已有良好的根群，但第二芽上花穗並未因根群的存在而獲良好發育；相反的，花穗不但無法發育，甚至新梢無法抽長及展葉。因此硬木插上花穗無法發育，似並不是單純的缺乏 Cytokinin(5.6.7.8.11.12.14.15.16) 所引起，碳水化合物無法充分利用，似亦應爲主要的原因之一。因爲硬木插上花穗的枯萎，原本就是花穗對養分競爭能力不足所造成(4.5.16)，而如今在僅選三芽的短插枝下，養分已不足，遑論先使萌芽、生根消耗養分後，又再去除第一節間，使養分更顯不足。因此即使在有根（代表 Cytokinin 的存在）、無新葉與頂梢（代表無養分競爭）的情況下，仍然無法使花穗發育。或許未來可選較長且較充實的插枝，先令第一芽萌發，再去除第一芽，令第二芽萌發的方法，成功的獲得結果盆栽。畢竟這是比較方便，且穩定，促使插枝先發根的方法。

葡萄先進國家在葡萄育種上均有數十年以上的歷史，不但經驗豐富，建有良好的育種流程，並因氣候適宜，在葡萄開花，雜交授粉與胚的成熟上，均無困難。如法國 Montpellier 葡萄中心所屬育種站，每年均可獲得 3～5 萬株雜交苗，即爲良好例証。相反的，本省並非葡萄原產地，許多引入的品種，只在離基部甚遠的部位才具結實潛力。經過冬季修剪後，開花極少或根本無花，（如 Thompson Seedless），當然也無法利用該品種的遺傳特性。且 3～4 月葡萄開花期，也是本省春雨期，常嚴重阻礙雜交授粉工作，再加上熱積溫高，果實成熟快，營養生長旺，養分易被新梢消耗，胚在無法獲得充足的時間與足夠的養分下，發育不全，更遑論本所果園易受外人侵入，不得不在果實尚未成熟前採收，種子萌芽率更低，往往辛苦一年所得的雜交後裔卻不到先進國家 2 %的數量，成爲目前育種工作的瓶頸。

因此吾人若能充分利用冬季修剪下，含結實潛力芽體的枝條，進行上述盆栽處理，除可取得舊法無法利用的配子，在溫室進行長期的雜交授粉工作外，並因該法所結的種子具有較高的萌芽率(16)，而可大大提昇育種效率，雖然該法所開的小花較小，除雄較不易，但就本所現今面臨的育種困境而言，實是值得繼續開發利用的育種技術。

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Studies on the promotion of inflorescence development on grape cutting[1]

W. Y. Wang[2] Alain Bouquet[3]

In this study, basal heating of grape cuttings, assigning budding order and NAA treatment were tried to increase the probability of root formation before bud burst; and trimming off young leaves and apex to eliminate their competition for nutrient were also done. The results showed that basal heating of cuttings and assigning budding order both formed new roots before bud burst, but only basal heating of cuttings make these flowers fertile.

Key Words : assigning budding order, fruiting cutting, inflorescence.

1. Contribution No. 1386 from Taiwan Agricultural Research Institute.
2. Assistant Horticulturist, Department of Horticulture, TARI, Wu-feng, Taichung, Taiwan 41301, R. O. C.
3. Rechercheur. Centre de recherches de Montpellier, Station de recherches viticoles. INRA. France.

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水稻品種(系)對稻熱病之抵抗性反應[1]

陳　隆　澤[2]

摘要：水稻抗稻熱病統一病圃自民國63年至78年，16年間先後計檢定2,118個水稻品種(系)。水稻罹病情形因年度及地區而異。一般言之，稉稻品種（系）較秈稻者易罹稻熱病，尤以穗稻熱病爲甚。稉稻品種（系）在第1期作亦較第2期作容易罹病，而秈稻者適相反。水稻品種（系）對葉與穗稻熱病之抵抗性反應成顯著之正相關，惟尚有少數例外。又水稻品種(系)在旱田式病圃對葉稻熱病之反應與其在水田式病圃者頗爲一致，但其發病程度較水田式病圃者嚴重。本省育成之抗病品種目前多數已淪爲感病，此顯示加強選育持久性抗病品種之重要性，尤其是稉稻。

關鍵詞：水稻、稻熱病、統一病圃。

稻熱病爲本省水稻最主要病害之一，尤其常發生於第 1 期作，使稻農蒙受嚴重損失。根據農林廳稻作主要病蟲害發生面積調查資料顯示本省過去數十年中，每年第1期作稻熱病發生爲害的稻田約佔稻作栽培面積之 7 ～24%，估計稻谷損失年達總生產量之1.5%(19)。稻熱病雖可以藥劑防治，但其成本高，藥效短，難於收到徹底防治效果，若施用不當，還易使病原菌產生抗藥性，並造成環境污染，栽植抗病品種被認爲是最經濟有效的防治方法(15,16,20)。因此本省各稻作改良場所均將抗病育種列爲主要育種目標之一。

本省水稻抗稻熱病育種始自1950年(16)，爲配合抗病育種工作之進行，自民國45年起在農復會之補助下，於本省稻熱病主要發生地區之宜蘭壯圍、南投竹山、屏東萬巒、臺東關山、及嘉義等地設置稻熱病統一病圃 5 處，並分由臺北、臺中、高雄、臺東區農業改良場及嘉義農業試驗分所等 5 個場所負責執行檢定工作，惟民國54年至62年間因故此項工作停辦多年，繼後在各場所要求下，於民國63年起恢復設置，並將檢定結果列爲新品種命名推廣之重要參考資料，但民國71年後統一病圃裁減僅保留嘉義及關山等 2 處。本文爰就民國63年至78年間稻熱病統一病圃檢定結果摘要報告於后，以提供有關人員之參考。

材料與方法

一、試驗材料：

參試品種（系）爲全省各稻作改良場所提供，包括新育成高級試驗以上品系及主要推廣品種，民國63年至78年間計檢定2,118個品種（系）。

二、試驗方法：

稻熱病統一病圃分水田式及旱田式病圃，其設置方式及稻熱病之調查方法與標準等分述如下：

㈠病圃之設置：

1. 水田式病圃：

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1. 臺灣省農業試驗所　研究報告第 1537 號。本試驗承行政院農業委員會補助部份經費，謹致謝意。
2. 本所嘉義農業試驗分所助理研究員。臺灣省　嘉義市。

水田式病圃在第1期作分別設置於壯圍、竹山、嘉義、萬巒及關山等５處，惟民國71年後僅設嘉義及關山等２處，民國65年及66年第２期作在嘉義病圃亦有設置。

試驗田採順序排列，重複兩次，參試品種（系）各種植兩行，行株距25×20公分，每行7株，每株3至5支苗，每隔兩個品種（系）種植一行感病品種 Lomello 及每行前後各植一株 Lomello 做爲感染源，另每隔10個品（種）系種植一行抗病品種臺農62號或關東51號，以資對照。每公頃 N、P_2O_5、K_2O 三要素肥料施用量分別爲320、54及60公斤。其中氮肥五分之一量及磷、鉀肥全量用做基肥，其餘氮肥分別在挿秧後15天、25天、35天及抽穗前25天施用。其他管理方法依照一般慣行法實施，惟應注意其他病蟲害之防治。

2. 旱田式病圃：

第1、2期作均設置於嘉義病圃。試驗田採順序排列，重複兩次，參試品種（系）條播，行長50公分，行距10公分，每品種（系）播種一行，每行播種５公克，每10行播種兩行感病品種 Lomello 及其中間夾播一行抗病品種臺農62號或關東51號，以資對照，周圍邊行全部播種 Lomello作爲接種源。每公頃 N、P_2O_5、K_20 三要素肥料施用量分別爲240、36及38公斤。整地時氮肥四分之一量及磷、鉀肥全量用做基肥與土壤混合均勻，剩餘氮肥分別在播種後15天、25天及35天做爲追肥施用。稻種發芽後，每天早、晚各在葉面上潑水一次，以保持濕度，促進發病。

(二)稻熱病調查方法與標準：

稻熱病發生之調查及標準，在民國63年至67年間係依舊有病圃之方法進行調查及歸級[6]。民國68年以後則參照國際稻熱病圃（IRBN）調查方法及標準實施[5,18]。茲分別敍述如下：

1. 民國63－67年：

(1)葉稻熱病：

秧苗期及挿秧後30、40、50、60及70天各調查一次。以肉眼依照葉稻熱病罹病程度規準圖[6]，每品種(系)調查10株，求其平均罹病面積率，再依下表查其指數、級別及反應。

病斑面積率(%)	0	0.2	0.5	1	2	5	11	25	55	88	100	120
罹病指數	0	1	2	3	4	5	6	7	8	8.5	8.8	9
級別	0	1		2		3		4		5		
反應	極抗 (HR)	抗 (R)		中抗 (MR)		中感 (MS)		感 (S)		極感 (HS)		

(2)穗稻熱病：

抽穗後20天及30天各調查一次，每小區調查10株之總穗數及被害穗數，求其平均罹病率。

罹病率 %	0－10	11－30	31－50	51－70	71－90	91－100
級別	0	1	2	3	4	5
反應	極抗 (HR)	抗 (R)	中抗 (MR)	中感 (MS)	感 (S)	極感 (HS)

2. 民國68年以後：

(1)葉稻熱病：

A.水田式病圃：

秧苗期、發病初期、中期及末期各調查一次，依據國際稻熱病圃調查方法，以肉眼依照下列調查標準分０－９級記載，每品種（系）調查10株，求其平均罹病級數，其標準及反應如下：

等級	標準	反應
0	無病斑。	極抗（HR）
1	葉片上祇有針頭大小之褐色病斑，多少不定，無壞疽斑點。	抗（R）
2	葉片上之褐色病斑較前者爲大，直徑約½mm，無壞疽斑點。	
3	葉片上有小而圓或微長形之壞疽灰色病斑，直徑約1－2mm，病斑邊緣褐色。	
4	葉片上感病型之稻熱病病斑，橢圓形，長1－2cm，通常爲兩個主脈所限制，有的病斑呈水浸狀態其外圍無一定的邊緣，感病型病斑佔葉面積2%以下。	中抗（MR）
5	葉片上感病型之稻熱病病斑佔葉面積10%以下。	
6	葉片上感病型之稻熱病病斑平均約佔葉面積之25%。	中感（MS）
7	葉片上感病型之稻熱病病斑平均約佔葉面積之50%。	感（S）
8	葉片上感病型之稻熱病病斑平均約佔葉面積之75%。	
9	葉片上感病型之稻熱病病斑約佔葉面積之100%。	極感（HS）

註1. 病斑祇發生於葉節處，致葉片由葉鞘上折倒者，視爲第4級。
註2. 罹病級數如介於相鄰兩級之間者以較嚴重之等級記錄之。

B.旱田式病圃：

播種後30天及40天各調查一次，調查方法與標準同水田式病圃。

(2)穗熱病：

抽穗後30天調查一次。依據國際稻熱病圃調查方法，以肉眼調查各品種（系）之罹病穗率，每品種（系）調查10株，求其平均罹病率，再依其罹病率分爲6級記載，其標準及反應如下：

等級	標準	反應
0	無被害穗。	極抗（HR）
1	罹病穗率爲 0.1～1.0%。	抗（R）
3	罹病穗率爲 1.1～5.0%。	中抗（MR）
5	罹病穗率爲 5.1～25.0%。	中感（MS）
7	罹病穗率爲 25.1～50.0%。	感（S）
9	罹病穗率爲 50.1～100.0%。	極感（HS）

結果與討論

一、水稻品種（系）對葉及穗稻熱病之抵抗性反應

自民國63年至78年間統一病圃計檢定2,118個品種（系），其結果列於表1，雖然歷年參加檢定之品種（系）與稻熱病發生程度各有不同，但在民國67年以前抗葉稻熱病之水稻品種（系）之百分比顯較抗穗稻熱病者爲低，其原因除因穗稻熱病易受抽穗期氣象因素之影響外[17]，兩種病害之歸級標準不一，似亦爲主要因素之一。例如葉稻熱病罹病率爲5%時，雖僅減產0.01%[9]，但仍被歸爲中感，而穗稻熱病罹病率達50%時，卻被歸爲中抗，雖其稻穀損失已達40%，殊不合理。因此經有關人員研討之後，自民國68年起改依國際稻熱病圃檢定調查方法及標準修改抵抗性反應之等級歸類，期以獲得較合理之檢定結果，由表1可見，自歸級辦法修改後，抗葉稻熱病之比例反較抗穗稻熱病者爲高。雖然現行檢定方法仍未臻理想，但實施多年來，其檢定結果尚稱合理。

表 1. 民國63年至78年間稻熱病統一病圃檢定結果

Table 1. Varieties and selections resistant to blast in uniform blast nurseries during 1974—1989.

Year	Entries tested	No. and perc. of resist. entries*	
		Leaf blast	Panicle blast
1974	48	13 (27.1%)	30 (62.5%)
1975	141	44 (31.2%)	84 (59.6%)
1976	175	45 (25.7%)	98 (56.0%)
1977	189	89 (47.1%)	100 (52.9%)
1978	140	30 (21.4%)	89 (63.6%)
Total	693	221 (31.9%)	401 (57.9%)
1979 **	164	109 (66.5%)	24 (14.6%)
1980	135	75 (58.6%)	48 (37.8%)
1981	147	95 (64.6%)	48 (32.7%)
1982	42	29 (69.1%)	24 (57.1%)
1983	113	79 (69.9%)	55 (49.1%)
1984	120	99 (82.5%)	47 (39.2%)
1985	140	113 (80.7%)	54 (38.6%)
1986	142	115 (81.0%)	76 (53.5%)
1987	132	76 (57.6%)	22 (16.7%)
1988	145	96 (66.2%)	17 (11.7%)
1989	145	105 (72.4%)	59 (40.7%)
Total	1,425	991 (69.5%)	474 (33.3%)
Grand total	2,118	1,212 (57.2%)	875 (41.3%)

* Resistant entries include those with reactions of MR, R, and HR.
** Classification of blast reaction changed in 1979.

水稻品種（系）對葉及穗稻熱病之抵抗性反應大體一致，兩者之間存有極顯著之相關關係(表 2)，顯示抗葉稻熱病者，大多能抗穗稻熱病，因此旱田式病圃雖不能檢定穗稻熱病，但仍可依其對葉稻熱病之反應而加以推測，惟兩種病害間之相關係數仍低於1，顯示尚有對兩者反應不一之品種（系）存在，因此進入高級產量試驗以上品種（系）仍有檢定穗熱病之必要。

表 2. 水稻品種（系）對葉及穗稻熱病抵抗性之相關關係

Table 2. Relationship of varietal resistance to leaf and panicle blasts.

Year	Correlation coefficient	
	1 st crop	2 nd crop
1974	0.86 **	—
1975	0.75 **	—
1976	0.76 **	0.37 **
1977	0.78 **	0.46 **
1978	0.79 **	—
1979	0.76 **	—
1980	0.73 **	—
1981	0.81 **	—
1982	0.99 **	—
1983	0.94 **	—
1984	0.84 **	—
1985	0.85 **	—
1986	0.68 **	—
1987	0.86 **	—
1988	0.78 **	—
1989	0.97 **	—

** Significant at 1 % level.

二、秈、稉稻品種（系）對稻熱病之抵抗性反應

一般言之，秈稻品種（系）較稉稻者抗病（表3），就兩種不同稻熱病之反應而言，在民國67年未修改歸級辦法以前，稉稻對葉稻熱病之反應似較穗稻熱病敏感，而秈稻對葉及穗稻熱病之反應則較相近。惟在68年修改等級標準後，秈、稉稻抗葉稻熱病之比率增加，尤以稉稻爲甚。此顯示今後之抗病育種，在秈稻方面宜注意穗稻熱病抵抗性之改良，而稉稻則必須對葉及穗稻熱病抵抗性之改良同時併行。

表 3. 秈稻與稉稻對稻熱病之抵抗性反應

Table 3. Reactions of Indica and Japonica rice to blast

Year	Percentage of resistant entries					
	Japonica			Indica		
	LBL[1]	PBL[2]	LBL and PBL	LBL[1]	PBL[2]	LBL and PBL
1974	27.7	63.8	18.8	0	0	0
1975	15.5	49.5	8.3	73.7	86.8	65.6
1976	5.8	42.1	5.0	70.4	87.0	67.9
1977	27.0	37.3	24.6	87.3	84.1	74.6
1978	5.9	57.8	5.9	63.2	78.9	55.3
Mean	16.4	50.1	12.5	73.7	84.2	65.9
1979	44.0	1.1	1.1	94.5	31.5	31.5
1980	37.2	32.1	30.8	92.0	46.9	44.0
1981	49.0	15.6	15.6	94.1	66.0	64.7
1982	60.7	46.4	46.4	85.7	78.6	71.4
1983	57.3	46.7	45.3	94.7	54.1	52.6
1984	77.8	28.9	28.9	96.7	70.0	70.0
1985	77.9	29.2	29.2	92.6	77.8	77.8
1986	77.8	47.0	47.0	96.0	84.0	84.0
1987	49.5	4.9	4.9	86.2	58.6	58.6
1988	62.3	9.0	9.0	87.0	26.1	26.1
1989	69.7	33.6	27.6	87.0	78.3	78.3
Mean	60.3	26.8	26.0	91.5	61.1	59.9

1. LBL=Leaf blast
2. PBL=Panicle blast

三、水稻品種（系）對稻熱病之期作性反應

本省稻熱病一般在第1期作較第2期作嚴重，尤以穗稻熱病爲甚（表4）。惟就不同稻型而言，其反應因期作而異。稉稻品種（系）在第1期作較第2期作容易罹病，而秈稻之反應則與稉稻相反，即第2期作之罹病率高於第1期作（表5），以往亦有類似現象之報導[3,4,11]，由此可知稉稻在低溫時較易感病，而秈稻則反在高溫下較易罹病，這可能與秈、稉稻之來源有關，即稉稻大多產自溫帶地區，爲害稉稻之生理小種在較低溫時發生頻率較高且致病性較強，而秈稻其親本大多來自東南亞之熱帶地區，在高溫下爲害秈稻之生理小種可能較多且具致病性使然[11]，在國外亦有類似之報導[13]。

表 4. 稻熱病在不同期作發生情形（嘉義，民國65及66年平均）
Table 4. Blast incidence in two crop seasons (Chiayi, mean of 1976 and 1977)

Crop season	Blast incidence (%)	
	Leaf blast	Panicle blast
1 st	25.4	63.4
2 nd	21.6	35.2

表 5. 水稻品種（系）對稻熱病之期作性反應（嘉義，民國65年）
Table 5. Reaction of rice varieties and selections to blast in two crop seasons (Chiayi, 1976)

Type	Crop seasons	Entries tested	Blast incidence (%)	
			Leaf blast	Panicle blast
Japonica	1 st	121	42.9	62.9
	2 nd	121	26.5	46.4
Indica	1 st	54	5.8	35.1
	2 nd	54	21.0	67.3

水稻品種（系）對稻熱病之期作性反應，對育種材料之篩選與檢定有很大的影響。本省稻熱病統一病圃一般均設置於第 1 期作，而各場所對抗病性之篩選亦多在第1期作進行，由於稉稻在第 1 期作較易感病，而在第 2 期作雖罹病較輕，但其在兩期作之反應尚稱一致（表 6），故就稉稻而言，在第 1 期作對稻熱病之篩選與檢定結果尚可代表其在第 2 期作之反應。而秈稻在第2期作感病之品種（系）往往在第 1 期作檢定時並不發病（表 6），故若僅在第1期作檢定或篩選則常有逃避現象，而獲得不正確之結果或選取感病之個體或系統。例如嘉農秈 8 號及11號在第 1 期作雖表現抗病，但在第 2 期作則呈感病反應，因此在民國63年推廣後於第 2 期作在中南部地區嚴重發生穗稻熱病[5]，爲避免重蹈覆轍，今後抗病育種之篩選與檢定，稉稻似可在第 1 期作進行，而秈稻則應在第 2 期作實施爲宜。

表 6. 秈、稉稻品種（系）對稻熱病之期作性反應（嘉義，民國65年）
Table 6. Reaction of Indica and Japonica rice to blast in two crop seasons (Chiayi, 1976)

Type	Variety or selection	Incidence of leaf blast (%)		Incidence of panicle blast (%)	
		1 st crop	2 nd crop	1 st crop	2 nd crop
Japonica	Tainung 67	100 (HS)	40 (S)	100 (HS)	30.3 (R)
	Hsinchu 56	100 (HS)	18 (MS)	90 (S)	66.3 (MS)
	Taichung 65	60 (S)	55 (S)	92.5 (HS)	41.6 (MR)
	Tainan 5	77 (HS)	40 (S)	98 (HS)	45.0 (MR)
	Tainan 6	0.8 (MR)	2 (MR)	49.1 (MR)	23.5 (R)
	Kaohsiung 53	72.5 (HS)	18 (MS)	75.6 (S)	31.2 (MR)
	Taitung 29	0.4 (R)	1.5 (MR)	23.9 (R)	17.5 (R)
Indica	Taita yu 43	1.0 (MR)	11 (MS)	33.8 (MR)	95 (HS)
	Taita yu 161	0.5 (MR)	25 (S)	16.9 (R)	100 (HS)
	Taichung native 1	1.3 (MR)	4.3 (MS)	43.2 (MR)	95 (HS)
	Chianung sen 8	0.2 (R)	67.5 (S)	18.2 (R)	100 (HS)
	Chianung sen 11	3.5 (R)	55 (S)	45.5 (MR)	100 (HS)
	Tainan sen 15	0.2 (R)	21.8 (S)	32.7 (MR)	87.3 (S)
	Tainung sen 12	0.2 (MR)	3.5 (MR)	37.8 (MR)	68.9 (MS)

四、水稻品種（系）在不同地區對稻熱病之反應

民國63年至70年之間參加檢定品種（系）在5個病圃中對稻熱病之反應列如表7，由表中可知，平均發病程度以關山病圃最為嚴重，竹山病圃次之，再依序為嘉義及萬巒病圃，而以壯圍病圃之發病最為輕微。再就民國71年至78年嘉義與關山病圃比較之，葉稻熱病以嘉義病圃較為嚴重，而穗稻熱病則關山病圃遠較嘉義病圃嚴重（表8）。雖然各病圃間之發病程度各有不同，但水稻品種（系）在各病圃間對稻熱病之反應達極顯著之相關關係[14]。顯示水稻品種（系）在各病圃間之反應頗為一致。病圃間之發病輕重除受各病圃發病期間之氣象條件或地理環境之影響外[12]，與生理小理分佈之不同可能亦有關係，據吳等[1]報告指出，分佈於關山病圃之生理小種種類較其它病圃為多（表9）。惟各病圃中主要生理小種之分佈大致相同而且數目不多，因此若不同小種係由不同基因所控制時，多數抗病基因可能因其所控制生理小種之分佈頻率太低而無法顯示其抗病性而被漏選，致可抗多種生理小種之廣幅抗病品種（系）在此情形下恐難於被選獲[2]，因此由統一病圃選出之抗病品種（系）應再送請國際稻米研究所（IRRI）參加國際稻熱病圃檢定，並請病理專家協助人工接種多數不同小種，以選獲眞正具有廣幅抗性之品種，目前本省抗稻熱病育種正朝此方向邁進中。

表7. 水稻品種（系）在不同地區對稻熱病之抵抗性反應（民國63—70年）
Table 7. Varieties and selections resistant to blast at each nuesery (1974—1981)

Nursery	Percentage of resistant entries		
	Leaf blast	Panicle blast	Mean
Chuanwei	56.5	62.6	59.6
Chusan	49.1	35.1	42.1
Chaiyi	53.2	43.6	48.4
Wanluan	54.3	48.3	51.3
Kuanshan	39.7	40.9	40.3

表8. 水稻品種（系）在嘉義及關山病圃對稻熱病之反應（民國71—78年）
Table 8. Varieties and selections resistant to blast at Chiayi and Kuanshan nurseries (1982—1989)

Nursery	Percentage of resistant entries		
	Leaf blast	Panicle blast	Mean
Chaiyi	60.9	53.9	57.4
Kuanshan	65.1	19.9	42.5

表9. 稻熱病生理小種在不同地區之分佈情形（民國64及66年）
Table 9. Distribution of physiologic races of blast at each nursery (1975 and 977)

Nursery	Physiologic race								
	IC—18	IC—26	IF—2	IF—4	IG—1	IG—2	IH—1	II—1	Total
Chuanwei	0	0	2	0	4	103	4	232	345
Chusan	0	0	1	0	0	40	4	134	179
Chaiyi	0	0	1	0	0	120	1	187	309
Wanluan	0	0	1	4	0	78	10	354	447
Kuanshan	11	10	6	39	0	42	1	150	250
Total	11	10	11	43	4	383	20	1,057	1,539
(%)	0.71	0.65	0.71	2.79	0.26	24.9	1.3	68.68	100

五、水稻品種（系）在水田式及旱田式病圃對葉稻熱病之抵抗性反應

水稻品種（系）在水田式病圃對葉稻熱病之反應與其在旱田式病圃者頗相一致，兩者間之相關係數達極顯著水準（表10），顯示旱田式病圃之檢定結果足可代表參試品種（系）在水田式病圃之反應。由於設置旱田式病圃所需人力、物力及土地面積等均較水田式病圃爲少，且有管理方便，發病均一之優點，故現行水田式病圃似可以旱田式病圃代替之[12]，至於旱田式病圃無法檢定穗稻熱病之缺點，似可由葉稻熱病之反應而間接推測，因葉與穗稻熱病之間存有極顯著之相關（表２）。而旱田式病圃在葉稻熱病檢定調查後，若能適當疏植、灌漑並加施追肥亦可進行對穗稻熱病之篩選，此項工作目前嘉義病圃正測試中。

一般言之，水稻品種（系）在水田式病圃中呈現抗病反應之比例較旱田式病圃者爲高，此顯示旱田式病圃之發病程度較水田式病圃者嚴重，其平均罹病級數約重１級（表11），因此具有中等程度抵抗性之品種（系）在旱田式病圃恐有被淘汰之虞，故旱田式病圃之有效運用仍有待進一步之研究。

表10. 水稻品種（系）在水田式及旱田式病圃抗病性之相關關係

Table 10. Relationship of varietal resistance to leaf blast in paddy and upland nurseries.

Year	Correlation coefficient	
	1 st crop	2 nd crop
1974	0.41 **	—
1975	0.78 **	—
1976	0.78 **	0.58 **
1977	0.69 **	0.64 **
1978	0.90 **	—
1979	0.94 **	—
1980	0.93 **	—
1981	0.88 **	—
1982	0.97 **	—
1983	0.87 **	—
1984	0.90 **	—
1985	0.92 **	—
1986	0.88 **	—
1987	0.95 **	—
1988	0.97 **	—
1989	0.94 **	—

** Significant at 1 % level.

表11. 水稻品種（系）在水田式與旱田式病圃之抗病性反應

Table 11. Reaction of varietal resistance to leaf blast in paddy and upland unrseries.

Year	Percentage of resistant entries		Leaf blast score	
	Paddy nursery	Upland nursery	Paddy nursery	Upland nursery
1974	72.3	14.0	2	4
1975	39.1	22.3	4	4
1976	39.4	29.7	4	4
1977	63.4	36.2	3	4
1978	28.6	19.2	4	4
1979	60.4	57.3	4	5
1980	79.7	53.9	3	5
1981	60.5	69.4	4	5

1982	66.7	42.9	4	6
1983	69.9	62.8	4	5
1984	82.5	75.8	3	4
1985	82.1	77.1	3	4
1986	78.9	69.0	4	4
1987	49.2	51.5	5	5
1988	62.8	60.0	5	5
1989	66.2	67.6	4	4
Mean	62.6	50.5	3.8	4.5

六、近年來新育成水稻品種對稻熱病之反應

自民國63年至78年間登記命名之水稻新品種計有42個，其中稉稻26個，秈稻16個。稉稻品種中有10個（38.5%）抗葉稻熱病，但抗穗稻熱病者只有 4 個（15.4%）。秈稻品種中抗葉稻熱病者有15個（93.8%），而抗穗稻熱病者有10個（62.5%），顯示秈稻新品種較稉稻者抗病（表12），惟目前秈稻種植面積只佔水稻總面積之7.7%，且有逐年遞減之趨勢[7]，使秈稻新品種之優良抗病性無法充分發揮，殊爲可惜。尤其目前主要栽培品種中90%以上均爲感病品種（表13），若遇氣候環境適宜稻熱病發生之年份，病勢將難於控制，後果實不堪設想，因此加速選育具有優良抗病性之稉稻新品種實爲當務之急。

表12. 民國63—78年新育成水稻品種對稻熱病之抵抗性反應

Table 12. Blast resistance of newly named rice varieties during 1974—1989

Type	Varieties tested	Blast resistance			
		Leaf blast		Panicle blast	
		Resistant	Susceptible	Resistant	Susceptible
Japonica	26	10 (38.5%)	16 (61.5%)	4 (15.4%)	22 (84.6%)
Indica	16	15 (93.8%)	1 (6.2%)	10 (62.5%)	6 (37.5%)
Total	42	25 (59.5%)	17 (40.5%)	14 (33.3%)	28 (66.7%)

表13. 水稻主要栽培品種之種植面積及其抗病性（民國77年）

Table 13. Reaction of top ten commercial varieties to blast in 1988

Variety	Type	Plant area		Blast resistance	
		ha	%	Leaf blast	Panicle blast
Tainung 67	Jap.	241,291	50.1	S	HS
Tainung 70	Jap.	48,998	10.2	HS	HS
Hsinchu 64	Jap.	36,294	7.5	HS	HS
Tainan 9	Jap.	33,332	6.9	MS	S
Taichung sen 10	Ind.	16,042	3.3	MR	MS
Taichung 189	Jap.	13,966	2.9	MR	S
Kaohsiung 142	Jap.	13,678	2.8	MS	S
Taichung glu. 70	Jap.	5,574	1.2	S	HS
Kaohsiung 139	Jap.	5,204	1.1	S	HS
Taichung native 1	Ind.	4,372	0.9	MR	MR
Total		418,751	87.0		

七、本省育成抗稻熱病稉稻品種之罹病化及未來因應對策

本省水稻抗稻熱病育種始自1950年代，四十年來雖先後育成不少抗病品種，但此等品種常在推廣後不久即逐漸失去抗性而淪爲感病，究其原因，除了因病原菌之變異外，主要爲以往採用之抗病親本大多來自統一病圃抗病性較佳之品種（系），而此些抗病材料僅在病圃經過 1 ～ 2 次之檢定，可能並未具有穩定之抗病性，又同一抗病親本亦可能同時被若干場所利用爲雜交材料，因此歷年來育成之抗病品種，其抗病性大多來自同一抗源，如表14所列之臺南6號、臺東29號、高雄141號及142號等其抗源均來自中國大陸品種荔枝紅，而臺農62號、69號及70號則來自CI5309，嘉農242號則來自NC4，臺南 9 號則源自JR80，臺中189號其抗源可能來自臺中在來 1 號。由於抗病性之遺傳背景相同，當此抗病基因失去抵抗性時，來源相同之抗病品種均有先後失去抗病性之可能[2,3]。

事實顯示，本省育成之稉稻抗病品種，其抗病性常不能持久，往往在命名推廣之同一年度即有罹病現象，最久亦不超過 3 年（表14），例如嘉農242號於民國45年推廣，但於民國47年即感病，而臺南 6 號、臺東29號、臺農69號及70號等則於命名推廣之同一年度就發生罹病現象，類似現象亦發生在日本[15,20] 及韓國[13] 等地。一個抗病品種之育成需花費多年人力與物力方能有成，若此抗病品種推廣後在短期間內就失去抗病性，則其投資頗爲不經濟，尤其本省水稻栽培以稉稻爲主，而稉稻抗病品種之快速罹病化，更值得有關方面之重視。

表14. 本省育成水稻抗病品種之抗源及其罹病化情形

Table 14. The resistant sources and its fading in some resistant varieties released in Taiwan.

Variety	Cross	Res. source	Year relea.	Year sus.	Res. period (year)
Chianung 242	Chianung yu 65/Chianung yu 123	NC 4	45	47	2
Tainung 62	Hsinchu 56//CI5309/ Hsinchu 56	CI5309	64	66	2
Tainan 6	Tainan 5/Kaohsiung 135	Lit-chi-hung	64	64	0
Taitung 29	Honewase/Taitung yu 265^2	Lit-chi-hung	68	68	0
Kaohsiung 141	Kaohsiung 139//Kaohsiung yu 973/Kaotsao yu 21	Lit-chi-hung	69	70	1
Taichung 189	Tainung 67/Taichung 187	Taichung native 1	72	75	3
Tainung 69	Tainung 61-M_5 10-1^4 /O. rufipogon//Tainung 60	CI5309	73	72	0
Tainung 70	Tainung 67/Chianung si pi 662028	CI5309	74	74	0
Tainan 9	Hsinchu yu 467/Tainan yu 162	JR80	74	75	1
Kaohsiung 142	Toyonishiki/Tainung 67// Kaohsiung 141	Lit-chi-hung	76	77	1
Mean					1

一般秈稻品種之抗病性較稉稻穩定而持久[2]。欲選育具有持久抗病性之稉稻品種，首先應擴大抗源，可選用國際稻熱病圃在世界各地經多年檢定具有穩定抗性之品種爲抗源親本，分別與本省優良稉稻品種（系）雜交，並利用回交及複交等方法以累積不同抗病基因育成具有持久性抗病品種或選育具有不同抗源基因之多品系品種。惟在選育過程中，育種材料除參加本省統一病圃篩選外，應再參與國際稻熱病圃檢定，並請病理專家協助接種不同生理小種，期以選獲眞正具有廣幅抗性品種，目前本省水稻育種在育種小組團隊合作下，已朝此方向邁進，期望不久將有優良抗病稉稻新品種育成。

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Reaction of Rice Varieties and Selections to Blast in the Uniform Blast Nurseries[1]

L. C. Chen[2]

Summary

A total of 2,118 rice varieties and selections were tested for their reaction to blast at two to five uniform blast nurseries during a 16-year period from 1974 to 1989. The incidence of blast varied with years and nurseries. In general, Japonica rices were more susceptible to the disease than Indicas, particularly to the panicle blast. Entries of Japonica type appeared more severe to blast in the first crop season while the Indicas were more sensitive in the second crop season. The reaction of rice varieties and selections to leaf blast was significantly correlated with that to the panicle blast, although a lack of agreement was observed in certain entries. Blast incidence recorded in the upland nursery was also observed to be closely related to that recorded in the paddy nursery, though the degree of incidence in the upland nursery was more severe than that in the paddy nursery. Unfortunately, most of newly developed blast-resistant varieties were easy to be breakdown and became susceptible within a period of 1 to 3 years after they were released for commercial cultivation in a wide area, this suggests the importance of developing more stable and longer lasting resistance to blast in rice, particularly for Japonica rice.

Key Words : Rice, Blast, Uniform blast nursery.

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2. Assistant Agronomist, Department of Agronomy, Chiayi Agricultural Experiment Station, TARI. Chiayi, Taiwan 60014, ROC.

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溫濕度對百合白絹病發生之影響[1]

謝廷芳[3]　杜金池[2]　蔡武雄[3]

摘要：百合白絹病係由 *Sclertium rolfsii* Sacc. 所引起，以人工接種風乾菌核於種球周圍1公分內之土壤，得知5粒菌核（接種源密度爲2.6個菌核/100立方公分土壤）即可致使百合出現黃化病徵，且被害度會隨著菌核接種數目的增加而增加。一般而言，自接種之日起二個星期內病害即可發生。八種受測試之百合品種中以 Polyanna 和 Cote d'Azur 較罹病，被害度分別爲0.56和0.50。百合全生長時期皆可遭受白絹病之爲害，被害度以露蕾期最高。本菌菌核於土壤平板上適合發芽溫度爲20～28°C，如先經乾燥低溫（20°C）處理三天再加水並移置於28°C下可提高發芽率。百合先經20°C處理一星期再移置於28°C下，最易遭受白絹病之爲害，與28°C之處理呈顯著差異（$\rho=0.05$）。最適合本菌菌核發芽和菌絲生長之水分潛勢爲－1～－10 bars, 低於－20 bars 時會降低其發芽率和生長速率。遞減土壤含水量會促進病害之發生，在土壤含水量先30%（W/W）後15%變化處理時被害程度爲0.75，與15%含水量處理者呈顯著差異（$\rho=0.05$）。當由20°C提高至28°C時，無論土壤含水量爲15或30%，在接種四星期後，百合被害度均達0.81，唯一不同只是在15%土壤含水量下病勢進展較快速。

關鍵詞：百合、白絹病、接種源密度、溫度、土壤濕度、被害度。

目前臺灣生產之百合以亞洲型雜交百合（*Lilium asiatic* hybrid），東方型雜交百合（*L. oriental* hybrid）和鐵砲百合雜交品種（*L. longiflorum* hybrid）爲主，提供切花觀賞之用。產區主要分佈於本省中部地區，計有臺中后里、水湳、軍功、南投埔里、彰化田中和雲林大埤等，栽培面積約40公頃且有逐年增加之趨勢。

Sclerotium rolfsii Sacc.（有性世代 *Athelia rolfsii* (Curzi) Tu & Kimbrough）係一多犯性土媒病原菌（soil-borne pathogen）。據 Aycock（1966）[(8)] 報告得知約可侵害100科500種植物，幾乎全世界均有病例發生[(33)]，而以熱帶地區發生最爲普遍[(8)]。在臺灣則經劉和吳氏[(2)]整理得知其寄主範圍有45科126種植物，而後又增加了三種觀賞植物[(4)]、菱角[(1)] 和百合[(3)] 共計131種。

1989年5月至7月在臺中后里、軍功、水湳、南投埔里，同年10月至1990年1月於軍功和彰化田中等百合栽培地區均發現白絹病之發生，造成種球腐敗和地上部黃化萎凋而死亡[(3)]。很多報告指出高溫多濕利於本病發生[(11.21.29)]，至於溫濕度如何影響病害發生則少有研究。故本研究之目的除了探討百合品種和生長時期對白絹病之罹病情形外，更進一步探究溫濕度對本病發生之影響。

材料與方法

一、菌株來源與菌核製備

由百合栽培區採集罹患白絹病之植株與菌核。罹病株以清水沖洗後置於濕室（moist chamber）

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1. 臺灣省農業試驗所　研究報告第 1538 號。本研究承農委會79—農建—7.1—糧—100(18)之經費補助。
2. 3. 本所所長。植病系助理及研究員。臺灣省　臺中縣　霧峰鄉。

下，待產生菌絲和菌核再行分離，挑取菌核以 1 %次氯酸鈉（NaOCl）殺菌三分鐘，隨後移至 2 %水瓊脂平板上。俟菌絲長出後，挑取菌絲尖端，培養於馬鈴薯葡萄糖洋菜培養基（PDA）斜面上。選取編號 Sr029 菌株（由臺中市軍功里百合栽培田分離）做爲本研究之供試菌株。

將乾稻草桿切成三公分長短，加水浸濕後裝入500毫升之三角燒瓶內，經二次121°C、1.05Kg/cm^2 20分鐘高溫高壓殺菌後，接種培養於 PDA 平板10天直徑 8 mm之 Sr029 菌絲塊，置於室溫（25±3°C）下培養二個月後形成大量菌核，取出菌核風乾後備用。

二、供試植物與土壤

供試植物爲來自荷蘭進口之黃色姬百合 Polyanna 品種之種球，經低溫（0～4°C）下處理二個月打破休眠後備用。土壤乃取自臺中縣霧峰鄉臺灣省農業試驗所試驗農場玉米田之壤土（砂：坋：黏＝40.9：48.0：11.1，pH＝5.3，有機質1.2%），經20目網篩過篩後，存放塑膠袋中備用。

三、接種源密度與病害發生之關係

將土壤裝入口徑18公分之素燒盆，栽植二顆周徑約14公分之百合種球後，分別於距離種球周圍 1 公分內之土壤接種5,10,20和40粒菌核，加水保持15%土壤含水量，以不接種菌核處理者爲對照組，每處理四重覆，置於24°C生長箱中每隔三天記錄發病情形。發病情形以被害度（Disease severity）表示，病徵分成五級：0＝植株健康，1＝植株¼葉片黃化，2＝植株½葉片黃化，3＝植株¾葉片黃化，4＝整株萎凋死亡。被害度與接種源密度計算公式如下：

被害度＝Σ（病害級數×該級病害株數）／(4×總調查株數)

接種源密度＝100N/V　　　$V=4\pi/3\left[(c/2\pi+1)^3-(c/2\pi)^3\right]\times n$

N＝接種菌核之數目　　　n＝百合種球數目

c＝種球周徑　　　V＝有效感染之土壤體積[23]

四、不同百合品種和生長時期對白絹病之罹病情形

取不同百合品種計姬百合黃色品種 Polyanna 和 Connecticut King, 白色品種 Roma, 桔紅色品種 Grand Paradiso 和 Positano, 粉紅色品種 Rosita, 桃紅色品種 Cote d'Azur 等七種和葵百合(*L. oriental* hybrid)紅色品種 Star Gazer 等分別栽植於18公分口徑素燒盆中，每盆栽植二顆種球，並接種10粒菌核，每個品種四重覆，置於24°C生長箱中，每隔一星期依病害級數調查病害發生情形。

以盆栽方式每隔20天左右種植姬百合 Polyanna 品種，在抽莖期、露蕾期、着色期和開花期，以人工挖開莖基部土壤，使露出種球部分，依前述方式接種菌核，再將土壤舖平，每個時期四重覆，置於生長箱中定期記錄病害發生情形。

五、溫度對菌核發芽和病害之影響

將20克土壤平舖於口徑 9 公分之培養皿內分成二組；第一組加入 4 毫升蒸餾水做成土壤平板，於平板上排放21粒菌核，分別置於16～32°C定溫箱中，每隔 4 °C爲一處理，另加二處理分別爲先於20°C靜置一天再移至28°C和先28°C靜置一天再移至20°C，每處理四重覆。第二組先將含菌核之未加水土壤平板依不同溫度處理三天後，再分別加入 4 毫升蒸餾水，而20和28°C交替處理者，於加水後再行之。二組試驗皆加水後第三天記錄菌核爆發式發芽情形。

另以盆栽方式栽植百合，並依前述接種方式接種，再分別將之放置於16,20,24,28和32°C生長箱中，增加二處理分別爲盆栽先於20°C靜置一星期後再移至28°C和先於28°C靜置一星期後再移至20°C，每處理四重覆，每隔一星期依前述病害級數記錄病害發生情形。

六、濕度對菌核發芽、菌絲生長和病害之影響

以玉米粉培養基（corn meal agar, CMA）做爲基礎培養基，依據 Robinson 和 Stokes 氏[28]調製不同水分潛勢之配方，加入不同量 KCl 使培養基水分潛勢分別爲－1、－5、－10、－20、－30和－50bars，經121°C、1.05Kg/cm^{2}壓力殺菌20分鐘後，加入無菌水以補足喪失之水分，並倒入口徑

9公分培養皿內，每皿20毫升，俟不同水分潛勢之培養基凝固後，每皿接入21粒菌核或直徑0.8公分之菌絲塊（於 PDA 平板上培養10天），每處理五重複，裝入塑膠袋，置於28°C定溫箱，每天記錄菌核爆發式發芽率和菌絲生長情形。

另將土壤加水調製成含水量爲15%（W/W）和30%（以105°C烘乾12小時之乾土爲基準，換算需加之水量），分別裝入塑膠袋內再置於口徑18公分之素燒盆內，依前述方法種植百合和接種菌核，並將塑膠袋密封，以保持水分。另外將含水量15%之處理靜置一星期後再加水調至30%並封口，相同的，將30%含水量處理之塑膠袋封口打開至適當大小使其水分漸漸蒸散至15%（約7天），再行封口，並隨時回測土壤含水量。每處理四重覆，每隔一星期依前述病害級數記錄病害之發生。

七、溫濕度交感效應對病害之影響

依前述方法將土壤含水量調成15%和30%。並以塑膠袋保持土壤含水量，然後置放於20和28°C生長箱中，另外加一處理先於20°C生長箱靜置一星期後，再移至28°C下，每處理四重覆，每隔7天記錄病害發生情形。

結　果

一、接種源密度與病害發生之關係

百合白絹病被害度隨著接種菌核數目之增加而增加（表一）。5粒菌核（接種源密度爲2.6個菌核／100cm³）接種於百合種球周圍土壤，在第12天時即可使百合出現黃化病徵，且隨著時間的增加，被害度亦逐漸提高，直至整株死亡爲止。接種10粒菌核時，被害度於第18天達到一半。被害度一般皆隨著菌核接種數目之增加而提高，且會提前發病。

表一、接種源密度與百合白絹病被害度之關係

Table 1. The relationship between inoculum density of *Sclerotium rolfsii* in soil and the disease severity of lily southern blight

Sclerotial number	Inoculum density[1) (Sclerotia/100cm³)	Disease severity[2)		
		12[3)	15	18
0	0.0	0.00	0.00	0.00
5	2.6	0.13	0.25	0.31
10	5.3	0.25	0.44	0.50
20	10.6	0.44	0.63	0.69
40	21.2	0.56	0.63	0.81

1) Inoculum density represented number of inoculating sclerotia in competence volume of soil around the 14 cm circum size of lily bulb within 1 cm.
2) Disease was divided into 5 grades, 0=No yellow, 1=¼ part of plant turns yellow, 2=½ part of plant turns yellow, 3=¾ part of plant turns yellow, 4=plant wilts and dies.
Disease severity=Σ(scale × number of diseased plant at relative scale)/(4 × total number of plants)
3) Days after inoculation.

二、不同百合品種和生長時期對白絹病之罹病情形

供試八個百合品種皆可受白絹病菌的爲害，其中以姬百合黃色種 Polyanna 和粉紅色種 Cote d'Azur 較罹病，而以白色種 Roma 和 Connecticut King 與葵百合 Star Gazer 較有抗性（表2）。

表二、百合品種與白絹病被害度之關係

Table 2. The relationship between lily varieties and disease severity of southern blight

Variety	Disease severity[1)]	
	2 wks[2)]	3 wks
Polyanna	0.25	0.56 a[3)]
Cote d'Azur	0.31	0.50 a
Rosita	0.28	0.44 ab
Positano	0.25	0.44 ab
Grand Paradiso	0.25	0.40 ab
Roma	0.25	0.31 b
Connecticut King	0.13	0.25 b
Star Gazer	0.13	0.25 b

1) The rating of disease severity is the same as in Table 1.
2) Weeks after inoculation.
3) Values followed by the same letter in each column are not significantly different at $p=0.05$ according to Duncan's multiple range test.

百合生長期大致分爲抽莖、露蕾、著色和開花等時期，白絹病菌在任何一個生長期均可爲害植株，造成黃化萎凋。其中以露蕾期較罹病，與著色期和開花期呈顯著差異（$p=0.05$）（表3）。

表三、百合不同生長期對白絹病感病度之影響

Table 3. Effect of different growth stages of lily on susceptibility to southern blight

Growth stage	Disease severity[1)]	
	2 wks	3 wks
Shoot emergence	0.25	0.56 ab[2)]
Visible bud	0.50	0.66 a
Coloured bud	0.25	0.33 b
Blooming	0.33	0.33 b

1) The rating of disease severity is the same as in Table 1.
2) Values followed by the same letter in each column are not significantly different at $p=0.05$ according to Duncan's multiple range test.

三、溫度對菌核發芽和病害之影響

以土壤平板測試菌核爆發式發芽率，得知16至32°C間皆可發芽，其中20～28°C的發芽率最高，介於80.95～84.13%之間，而菌核經由20和28°C交互處理，並未能提高其發芽率（表4）。菌核先於乾土表上3天後，再加水潤濕，除了16和20°C處理外其餘溫度處理下菌核發芽率均有明顯降低現象。但20°C乾土中先靜置三天後再加水置放一天移至28°C下則發芽率高達93.65%（表4）。

表四、溫度對白絹病菌菌核發芽之影響

Table 4. Effect of temperature on germination of sclerotia of *Sclerotium rolfsii*

Temperature[1)]	Germination (%)	
	Wet	Dry→Wet[2)]
16	53.97	84.13
20	84.13	84.13
24	84.13	71.43
28	80.95	63.49
32	65.08	41.27
20→28	84.13	93.65
28→20	84.13	58.73

1) The soil plate that contained 20g dry soil and 21 sclerotia was added with 4 ml distilled water and incubated under different temperature conditions. 20→28 represented the soil plate with sclerotia was transferred to 28°C after 1 day of incubation under 20°C, while 28→20, the reverse.
2) Dry→Wet represented soil plate was maintained under dry condition for 3 days, then 4 ml distilled water were added.

百合白絹病的發生受溫度變化的影響極大，24°C以下之溫度處理雖經過三星期未見病徵出現，相同地先將百合置於28°C一星期再行移入20°C下處理亦無病害發生。然而先將百合以20°C處理一星期後再移至28°C下，則病害發生極爲嚴重，被害度高達0.71，與28°C處理之被害度呈顯著差異（$\rho=0.05$）（表5）

表五、溫度對百合白絹病發生之影響

Table 5. Effect of temperature on the occurrence of lily southern blight

Temperature[1)]	Disease severity[2)]	
	2 wks	3 wks
16	0.00	0.00 c[3)]
20	0.00	0.00 c
24	0.00	0.00 c
28	0.25	0.33 b
32	0.25	0.50 ab
20→28	0.44	0.71 a
28→20	0.00	0.00 c

1) Lily plants were cultured in the growth chamber under different temperatures. 20→28 represented lily plants were transferred into 28°C condition after 1 week of incubation under 20°C, while 28→20, the reverse.
2) The rating of disease severity is the same as in Table 1.
3) Values followed by the same letter in each column are not significantly different at $\rho=0.05$ according to Duncan's multiple range test.

四、濕度對菌核發芽、菌絲生長和病害之影響

水分潛勢對菌核發芽有所影響，在－1～－10 bars 之間，菌核爆發式發芽率分別爲97.9%和91.7%，而低於－20 bars 時，菌核發芽率隨即降低，尤其在－50 bars 時菌核不發芽（表6）。在不同水分潛勢下，菌絲生長情形大致與菌核發芽情形相似，－1～－10bars 菌絲生長良好，生長速率在29.3 mm/day 以上，然而低於－20 bars 時，菌絲生長速率明顯降低，尤其在－50 bars 下菌絲塊於第五天以後才見菌絲緩慢生長（表6）

表六、不同水分潛勢對白絹病菌菌核發芽和菌絲生長之影響

Table 6. Effect of different solute water potential on sclerotial germination and mycelial growth of *Sclerotium rolfsii* on corn meal agar.

-Bar[1)]	Sclerotial germination[2)] (%)	Mycelial growth (mm)[3)]					
		1	2	3	4	5	6
1	97.9	15.5	52.8	79.8			
5	91.7	15.8	53.5	79.0			
10	91.7	16.0	49.8	74.5			
20	79.2	12.5	36.0	55.0	79.5		
30	45.8	0.0	18.3	29.5	45.0	58.5	75.5
50	0.0	0.0	0.0	0.0	0.0	9.5	11.8

1) The solute potential was adjusted to values between −1 to −50 bars by adding appropriate amounts of KCl into corn meal agar.
2) Each value represents the mean of five replicates, sclerotial germination was rated after 72 hrs of incubation at 28°C.
3) An 8 mm diameter of mycelial disk (from the 7−day−old colony on PDA) was placed onto the center of medium, and the mycelial growth was measured each day after inoculation.

土壤水分含量在30%情況下比在15%時較利於白絹病之發生，接種三星期後之被害度分別爲0.63和0.38。土壤水分含量在15和30%之間交替變化時亦會促進被害度，其中土壤含水量先維持30%一星期後再慢慢降至15%時被害度爲0.75最高，且與15%含水量處理者呈顯著差異（ρ=0.05）（表7）

表七、土壤濕度對百合白絹病發生之影響

Table 7. Effect of soil moisture on the occurrence of lily southern blight

Soil moisture[1] (%)	Disease severity[2]	
	2 wks	3 wks
15	0.13	0.38 b[2]
30	0.44	0.63 a
15→30	0.25	0.50 ab
30→15	0.50	0.75 a

1) Soil was adjusted to 15 and 30% MHC by adding appropriate amount of distilled water (determined by calculation after drying soil sample at 105°C for 12 hrs) and kept moisture with plastic bag. 15→30 represented the soil was maintained at 15% MHC for 7 days and then added with appropriate amount of water to adjust soil mosture to 30% MHC.30→15 represented soil at 30% MHC was progressively dried by natural way down to 15% MHC.
2) The rating of disease severity is the same as in Table 1.
3) Values follow by the same letter in each column are not significantly different at ρ=0.05 according to Duncan's multiple range test.

五、溫濕度交感效應對病害之影響

百合生長在20°C環境下，土壤含水量維持15%時，其被害度較30%高，然而在28°C下，則以30%土壤含水量者較高。生長溫度由 20°C 提高至 28°C 時，無論土壤含水量爲30或15%，四星期後被害度均達0.81，惟在15%土壤含水量下病勢發展較爲快速。由上述結果可知溫度變化，利於病害發生（表8）。

表八、在不同溫度下土壤濕度對百合白絹病發生之影響

Table 8. Effect of soil moisture on the occurrence of lily southern blight under different temperature condition

Temperature[1] (°C)	Soil moisture[2] (% MHC)	Disease severity[3]		
		2 wks	3 wks	4 wks
20	15	0.06	0.19	0.31
	30	0.00	0.00	0.13
20→28	15	0.69	0.81	0.81
	30	0.44	0.63	0.81
28	15	0.31	0.38	0.44
	30	0.50	0.56	0.69

1) Lily plants were cultured in the growth chamber under different temperatures. 20→28 represented lily plants were transferred into 28°C condition after 1 week of incubation under 20°C.
2) Soil was adjusted to 15 and 30% MHC by adding appropriate amount of distilled water (determined by calculation after drying soil sample at 105°C for 12 hrs) and kept moisture with plastic bag.
3) The rating of disease severity is the same as in Table 1.

討　論

白絹病菌（*Sclerotium rolfsii* Sacc.）爲一土壤傳播性病原菌，有關本菌的生理、生態與防治研究爲數甚多，但始終無法完全將之防除[2.22]，可能原因是由於它寄主範圍非常廣，而且具強而有力的殘存構造一菌核[22]，會依隨土壤環境之變化而決定繁殖或休眠。本菌腐生能力非常強，在土壤中可佔據未腐熟的有機質，菌絲快速生長並形成大量菌絲[11]，在臺灣百合種植時，花農常施用大量有機質，無疑地提供白絹病菌有利的生長基質，以致病害發生非常普遍（除了雲林大埤外，其餘百合栽培區均有白絹病發生）。除了有機質外，影響病害發生最大的因子是溫濕度，Punja(1985)[22] 認爲在高溫多濕的條件下會促進病害的發生，無關乎有機質之存在與否。

土壤中菌核存在的密度與病害嚴重程度有直接的關係。Backman 等(1981)[9] 利用土盤技術（soil-tray technique）偵測500克土壤中菌核數目與甜菜白絹病發生率呈明顯正相關，相關係數高達0.83以上。在溫室中，1公斤土壤內含有1,000個菌核的接種密度，可造成約75％的大豆幼苗遭受侵害[7]。然而 Punja(1986)[23]在溫室條件下，測試接種源密度在每100立方公分土壤中含2.5個菌核時即可100％侵害蘿蔔根。兩者之間的差異在於後者所用之單位土壤，以蘿蔔主根周圍土壤爲主（土表距根 3公分、5公分土深距根1公分內之土壤）。本實驗接種5粒菌核（接種源密度爲100立方公分土壤中含2.6粒茵核）於百合種球周圍1公分土壤中，即可造成病害，且被害度會隨著接種源密度的增加而提高。

有關作物品種抗白絹病菌 *S. rolfsii* 的報告很多，如花生[14]、大豆[6]、羽扇豆[15]、甜菜[12] 和水稻[22] 等，然抗病機制猶未確定，Higgins[19] 指出花生抗白絹病菌在於莖部皮層厚和氣孔少，其它可能還包括組織木質化[6]，含高量鈣[10.24] 和酚化物或草酸氧化酵素[18.24] 等之存在。本研究測試八種百合品種，對白絹病之抗感病性，其中以姬百合 Roma、Connecticut King 品種和葵百合 Star Gazer 品種較具抗性。至於品種間組織解剖學和生理學上之差異爲何，則有待進一步研究。許多學者指出植物對本菌之抗性會隨著株齡而增加[17.19]。Epps[16] 等指出具木質莖和根的植物會隨著株齡而漸具抗性，然而草本莖和根之植物則否。百合乃屬於後者，在百合生長時期的任何階段皆可受到本病的爲害，以露蕾期尤甚，可能在此時期植株組織或養分發生巨大變化而增加罹病度。

白絹病菌（*S. rolfssii*）菌核發芽方式有爆發式(eruptive germination)和菌絲式（hyphal germination）兩種[26]。菌核在培養基和田土上的爆發式發芽最適溫度爲21～30°C，低於或超過此溫度範圍時，發芽率明顯降低[25]。本研究結果亦顯示最適菌核爆發式發芽溫度介於20～28°C之間，溫度變化（20和28°C交互處理）未能提高其發芽率。若將菌核排放於乾土表上三天再加水濕潤時，在24～32°C處理下，菌核發芽率明顯降低。將菌核乾燥再濕潤時可促進營養泌出[13.31]，Punja 和 Grogan[26] 將菌核放在 $CaCl_2$ 乾燥箱中20小時後，用水沖洗五小時使菌核乾重量減少25％，而滲露出氨基酸和碳水化合物之量最多，這些營養物質可增進土壤微生物活力，而抑制其發芽或殺滅菌核[31]。

白絹病在土壤溫度20～40°C下都可危害水稻，造成苗立枯，而最適病害發展的溫度爲25～35°C，其中以30°C下被害度最嚴重[32]。本研究測試百合白絹病最適發病溫度爲28～32°C，如將百合先置於20°C下再移入28°C生長箱時，可增加被害度。百合植株生長的溫度需求以20°C左右爲佳，但本病在28°C左右易於發生，其原因可能除了溫度利於病原菌的生長外，植株處於較高溫下而呈弱勢生長，使病原菌有機可乘應屬主因。有關此方面的問題值得進一步探討。

土壤濕度與菌核發芽的相關研究很多[5.20.25]，但與病害的關係則較少。在25％～75％土壤含水量下菌核發芽率均在68％以上，但超過75％含水量時發芽率隨即降低[5]；以水分潛勢Ψs而言，最適發芽者爲－2.5～－10 bars 之間，低於－10 bars 時菌核發芽受阻[25]，與本研究測定水分潛勢對菌核

發芽和菌絲生長的結果相符。在土壤含水量50～75%下由 *S. rolfsii* 引起的小麥莖和根腐病比飽和含水量嚴重[27]，而含水量及土壤質地與病害發生關係密不可分，在排水性良好的砂質土壤[32] 和坋質土含量高、保水性佳的土壤，均利於病害發生[30]。本研究亦得知土壤含水量15和30%下百合白絹病都可發生，尤其當土壤含水量由30%慢慢降至15%時，被害度最高。此結果說明了田間白絹病總是發生在灌溉後或下雨後土壤漸乾時。

綜合溫度和土壤濕度交感作用對病害的影響，可清楚地發現土壤濕度的效應不比溫度效應強。也就是說，高溫（28°C）下的被害度比低溫（20°C）下高，無關土壤濕度，且在溫度變化下，土壤濕度只扮演著控制病勢發展速度快慢的角色而已。

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Effects of temperature and moisture on the occurrence of lily southern blight caused by *Sclerotium rolfsii* Sacc.[1]

T. F. Hsieh[2] C. C. Tu[3] and W. H. Tsai[2]

Summary

Lily southern blight was caused by *Sclerotium rolfsii* Sacc. When 5 dried sclerotia (Inoculum density about 2.6 sclerotia per 100 cm^3 of soil) were inoculated into soil around the bulb of lily within 1 cm, the yellowing symptom could appear obviously within 2 weeks. Moreover, the disease severity increased gradually with the increasing number of inoculating sclerotia. Eight varieties of lily tested for resistance to *S. rolfsii* (Sr029) indicated that all of them could be infested in 2 weeks after inoculation. Varieties Polyanna and Cote d'Azur of *Lilium asiatic* hybrid group were more susceptible than others. All of the growth stages of lily were susceptible to the pathogen especially at the visible bud stage. On soil plate, the maximum sclerotial germination occurred at 20-28°C. The percentage of germination was increased when the sclerotia were incubated under drying condition for 3 days at 20°C and then remoistened and placed at 28°C. Consistently, the greater disease severity was obtained when the lily plants were transferred into the 28°C condition after 1 week of incubation under 20°C. In general, the best solute water potential for sclerotial germination and mycelial growth was between −1 and −10 bars. However, with decreasing of solute water potential from −10 to −50 bars, the percentage of germination and growth rate were decreased. Changing soil moisture promoted disease severity; the disease severity was about 0.75 when soil moisture was adjusted to about 30 % moisture holding capacity (MHC) and then progressively dried by natural way down to 15% MHC. Moreover, under the condition that tested plants were tranferred from 20 to 28°C, the disease severity of both soil moisture treatments (15 and 30% MHC) was up to 0.81 after 4 weeks of inoculation, however, it showed that the disease development was faster at 15% MHC.

Key Words: lily, *Sclerotium rolfsii* Sacc, inoculum density, temperature, soil moisture, disease severity

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2. Respectively, Assistant and senior Pathologist, Department of Plant Pathology, TARI, Wu-feng 41301, Taichung, Taiwan, ROC.

3. Director,TARI.

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臺灣地區西瓜根瘤線蟲之發生及防治[1]

杜金池[2] 程永雄[3] 王貴美[2] 蔡東纂[4]

摘要：本省西瓜栽作型態大抵分為三種：旱田輪作、蔗田輪作、及河床地連作；其罹患根瘤線蟲之發病率分別為55%，57.5%，及60%，病原主要為南方根瘤線蟲(*Meloidogyne incognita*)爪哇根瘤線蟲(*M. javanica*)次之。旱田西瓜園之根瘤線蟲族群高峰期在7月至9月間，而12月至1月較低；蔗田西瓜園之高峰期自6月至10月，而低族群密度在1月至3月，河床地西瓜園之根瘤線蟲族群消長曲線最尖，在7、8兩個月為高峰，11月後族群顯著地降低。田間調查結果顯示，根瘤線蟲和蔓割病菌之複合感染率，以河床地之16.5%為最高，蔗田之11.5%次之，旱田之11%最低。田間防治試驗結果顯示，以施用幾丁質添加物(Clandosan)，殺線蟲劑抗蟲得(10% Controven G.)，及燻蒸劑溴化甲烷(Bromomethane)對根瘤線蟲之防治效果最佳，其根瘤指數分別為2.0、2.1及2.8和對照組之4.0有顯著差異；而果實品質以施用幾丁質添加物者最佳；其平均甜度為11.5 Brix；產量則各處理間以幾丁質添加物及一般有機質添加物為最好，但統計分析結果，差異不顯著。

關鍵詞：西瓜、根瘤線蟲、族群消長、幾丁質添加物、殺線蟲劑。

西瓜是本省重要農產品之一，每年種植面積都在兩萬公頃以上，以臺南、雲林、花蓮、彰化、嘉義、臺東及高雄等縣市為主要產區[1]。西瓜係葫蘆科植物，耐旱性強、耐濕性不佳，不適合粘質排水不良之地區栽培；農友們通常選擇排水良好的旱田、砂丘、河床砂洲等砂質壤土或砂質地種植。近年來更有許多瓜農向臺灣糖業公司承租蔗田休閒地栽植西瓜，蔚為風氣，成為本省西瓜產業特色之一。葫蘆科植物本為根瘤線蟲良好寄主[15]，砂質土壤更適合線蟲之移行孳息[25]，加以蔗田中分佈廣泛的線蟲族群[4]，致本省西瓜線蟲病害發生日益嚴重，尤其以根瘤線蟲之為害最值得重視。罹根瘤線蟲病之西瓜株地上部有明顯的矮化、葉片變小、黃化及微量元素缺乏等症狀；地下部則有根系結瘤情形，在田間甚易辨認(圖片1、5)。多年來西瓜苗常稼接扁蒲以降低蔓割病之發生率，但田間狀況顯示以扁蒲為砧木之西瓜株很容易感染根瘤線蟲，而和蔓割病菌複合感染。這和根瘤線蟲侵入西瓜株根系所造成的機械傷害及生理病變助長蔓割病菌之侵染不無關係[16]。

本省之西瓜根瘤線蟲病，早在1924年，澤田兼吉氏於臺南地區已發現[9]。1972年，黃等[6]在全省主要作物線蟲相調查專刊中亦有記錄，但未作進一步的鑑定及其他的研究。西瓜之栽培最忌連作，根瘤線蟲問題是主要原因之一。1985年一項全球性的作物線蟲病問卷調查統計結果指出，瓜類因線蟲病所遭受的損失率為13.8%[23]。本省可耕地無多，連作在所難免，農民的損失相隨而來，因此，本報告旨在調查本省西瓜根瘤線蟲病害之發生情形及其病原種類、分佈和族群消長，從而尋求有效的防治方法。

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1. 臺灣省農業試驗所 研究報告第1539號。本研究承行政院農委會補助(78一農建一7.1糧35(30))，本所植病系蔡武雄博士提供寶貴意見，謹此致謝。
2. 本所所長及植物病理系助理。臺灣省 臺中縣 霧峰鄉。
3. 本所嘉義分所所長。臺灣省 嘉義市。
4. 國立中興大學植物病理系講師。臺灣省 臺中市。

材料與方法

一、供試土壤及根部樣品之採集

自民國76年 7 月至78年 6 月間從本省旱田、蔗田及河床地等三種不同土壤型態之西瓜集約栽培區內之西瓜園，逢機設定四個採樣小區，每小區 6 株，標示後於植前及植後 1 、 3 、 5 個月挖取根圈土壤及根系樣品，置於塑膠袋中攜回，即進行各項分離試驗。

二、線蟲之分離及檢視

土壤樣品依改良柏門氏漏斗分離法（modified Baermanns funnel method）[6]，將直徑19公分的漏斗置於特別設計之分離架上，底部連接 7 公分長之橡皮管，其下方銜接一指形管，漏斗上置一60孔目之網篩，而後注入清水（八分滿）；再將採回之土樣100公克，以雙層衛生紙包妥，置於漏斗中，靜置36小時後，取下指形管，將此濾液倒入 Syracuse 鏡檢皿內鏡檢，並計算根瘤線蟲雄蟲及幼蟲數目。根部樣品則以緩和之水流洗淨後 ， 於解剖顯微鏡下 ， 以解剖刀切開根組織，檢視雌蟲及卵塊。

三、雌蟲陰門模紋（perineal pattern）之製作與觀察

以解剖刀剖開根部結瘤組織，挑取成熟雌蟲，切取蟲體後端三分之一部分，依序以清水、45%乳酸、25%甘油清除內含物，洗淨後，以解剖刀切取含陰門膜紋之體皮，平置於滴有乳酚溶液（plain lactophenol solution）載玻片之上，覆蓋蓋玻片，於光學顯微鏡下觀察陰門膜紋的形態，依據 Taylor and Sasser[26] 鑑定其種類。

四、根瘤線蟲爲害指數之計算

1. 線蟲繁殖力（Reproduction factor）之測定[28]：在標定區域內所測得植後 5 個月的根圈土壤根瘤線蟲數除以植前根瘤線蟲數，即爲該區根瘤線蟲之繁殖力，簡稱 Rf 值。

2. 根瘤指數（Root-knot index）之分級：於植後 5 個月，拔取標定區域內西瓜株，檢視其根系，依罹根瘤程度之不同分成以下五級，即：

根瘤指數（RKI）	結瘤程度（%）
0	0
1	1～10
2	11～30
3	31～50
4	50以上

3. 罹病指數（Disease index）之計算：其計算公式爲

$$DI=\frac{\Sigma(n\times RKI)}{4N}\times 100$$

n：各等級株數

RKI：根瘤指數

N：總株數

五、接種試驗

1. 供試西瓜苗來源：自農友種苗公司購得之金蘭西瓜種子，先以育苗袋(溪沙：花根旺＝2 ：1）播種催芽，待西瓜苗之第四片葉伸展後，即移植於消毒過之栽培土（沙質壤土：花根旺＝2 ：1），俟其長至20公分左右時即可供作接種用。

2. 接種方法：自根瘤上挑取單一卵塊，於24°C恆溫箱中孵化成二齡幼蟲，計數400隻，導入供試植物根圈。並設對照組，不予接種。本試驗重複三次，所有供試植株置於平均溫度27.5°C，相對濕度

65%之溫室中栽培。

六、本省主要西瓜栽培區根瘤線蟲病、蔓割病及二者病原之複合感染之調查。

於上述西瓜主要栽培區，調查本省西瓜根瘤線蟲病，蔓割病及二者病原之複合感染發生之情形。調查方法如下：

1. 根瘤線蟲病：如上述罹病指數之計算。

2. 蔓割病：採用日本奈良試驗場的西瓜成株期發病百分率換算公式[3]，即發病百分率＝

$$\frac{(\text{枯死株數}\times 1+\text{重症株數}\times 0.7+\text{中症株數}\times 0.5+\text{輕症株數}\times 0.2)}{\text{田間株數}}\times 100$$

其中，枯死：全株萎凋死亡；重症：每株內有70%的蔓萎凋；中症：每株內有50%的蔓萎凋；輕症：每株內有20%的蔓萎凋。

3. 二者病原之複合感染：複合感染率＝$\frac{\text{二者複合感染之株數}}{\text{調查株數}}\times 100$

七、西瓜園內根瘤線蟲族群之消長

於臺中縣烏日鄉、雲林縣褒忠鄉及臺南縣白河鎮，分別選定典型的河床地、旱田及蔗田西瓜園；每隔一個月測量標定區內根瘤線蟲數，為期兩年，以尋求線蟲族群之消長曲線。

八、土壤處理對西瓜根瘤線蟲之防治效果

供試植株：自農友種苗公司購得以扁蒲作砧木之健康金蘭西瓜苗，平均每株帶4至5片葉。

供試土壤與線蟲：臺中縣烏日鄉罹南方根瘤線蟲病之西瓜園砂質壤土。並取其罹病之西瓜根瘤，挑取單一卵塊，培養於24°C恆溫箱，孵化為二齡幼蟲，供接種用。

供試藥劑或添加物：

(1)殺線蟲劑抗蟲得（10% Controven G.）：S-(tertbutyl-thio) methyl-O, O-diethyl phosphorodithioate, U.S.A. Cyanamid Co.

(2)燻蒸劑溴化甲烷（Bromomethane）：Methyl Bromide 含98%（W/W）；Chloropicrin 含2%（W/W），U.S.A. The Dow Chemical Co..

(3)幾丁質添加物（Clandosan）：Chitin（poly-N-acetyl-D-glucoseamine）Protein 含25%，Organic buffer, Urea and Minerals 含75%，U.S.A. Igene Biotechnology Inc.

(4)一般有機質添加物（長青肥）：sawdust、pigdung、peanut shell, 其N：P：K=3：5：8，Taiwan, Evergreen LTD.

(5)烏肥 $Ca(CN)_2$：含 N,18%；CaO,50%以上，U.S.A. Cyanamid Co.

1. 溫室盆栽防治試驗：將上述之供試土壤，依各試驗資材之使用法（如后）處理後，每十公斤土分裝入48公分×18公分×21公分長方形塑膠盆缽，每盆栽種3棵西瓜苗，於每棵西瓜苗之根圈接種上述供試線蟲50隻。各處理依序為：殺線蟲劑抗蟲得：依據農林廳植物保護手冊推薦使用法，於西瓜種植前，植穴施用2公克。土壤燻蒸劑溴化甲烷：平均添加12毫升於40公斤土壤，以塑膠布完全密封，一星期後掀開，待氣體揮發後，拌匀，分裝入盆缽後種植西瓜。幾丁質添加物、一般有機質添加物長青肥及烏肥：每一盆缽土壤各別施用40、120及25公克，攪拌均匀，一星期後植入西瓜苗。以不作任何處理為對照組。西瓜定植後第30天、60天調查根圈土壤線蟲數，並於第60天測量西瓜蔓之長度及全株鮮重，計算根系之根瘤指數。

本試驗六處理，四重覆。在平均溫度27.5°C，相對濕度為65%之溫室中進行。將其結果以鄧肯氏多變域法分析。

2. 田間防治試驗：試驗地點在臺中縣烏日鄉砂質土旱田，其耕作制度為休閒（12月～1月）—西瓜（2月～7月）—雜作：玉米、花生、胡麻（8月～11月）—休閒；在各作物種植中期測得每100

公克根圈土根瘤線蟲數目分別為：0.2（0－8），412（106—943），3.8（2—45），顯示根瘤線蟲族群消長頗具規則性。處理方法：殺線蟲劑抗蟲得，於西瓜種植前植穴處理，每株20公克。土壤燻蒸劑溴化甲烷，每公頃10公升，植前施用，一星期後翻土，第二星期俟氣體揮發後種植西瓜。幾丁質添加物、一般有機質添加物長青肥及烏肥，於植前拌土作畦，每一公頃各別施用600、2000、200公斤。以不作任何處理為對照組。

田間設計：採逢機完全區集設計，六處理四重複，每小區10株。

防治效果之測定：依處理前及處理後30、90、135天之根圈土壤線蟲數及採收時根瘤指數多寡，每株西瓜留果4個，測其平均果重，並以糖度計（日本 Atago 公司，機型N－1）測其平均甜度，代表西瓜質量，並以鄧肯氏多變域法，分析其差異顯著性。

結　果

一、本省西瓜根瘤線蟲病之發生

在旱田西瓜園，根瘤線蟲族群之消長和前期作物之種類及土壤之性狀有密切關係，由於多年來耕作制度一成不變，如臺南縣的安南、大內及山上；臺中縣的大肚；花蓮縣的吉安等大宗西瓜產地，根瘤線蟲病之發生很嚴重，地上部有明顯黃化、矮化及葉片變小等症狀，罹病根系則結瘤纍纍且伸展不良，剖開根瘤可見許多雌蟲及卵塊（圖片1，5，6），線蟲種類以南方根瘤線蟲（M. *incognita*）為多（圖片4），爪哇根瘤線蟲（M. *javanica*）較少（表一）（圖片7）。

表一、臺灣旱田西瓜園根瘤線蟲之發生

Table 1. *Meloidogyne* spp. found parasitizing on watermelon in uplands of Taiwan

西瓜品種 Variety	線蟲數目／100克根圈土 No. of nematodes/100 g.soil					根瘤指數 Root-knot index	線蟲種類 Meloidogyne spieces	栽培地點 Locality	前期作物 Preceding crop
	植前 Pre-plant	植後（月）post-plant (month) 1	3	5	R factor Pf/Pi				
富寶2號	31.2	29.1	314.2	521.4	17.6	3.2	M. *incognita*	屏東楓港	黃秋葵
金蘭	47.0	53.5	466.2	428.6	8.0	4.0	M. *incognita* M. *javanica*	臺東卑南	蕃茄
金蘭	18.4	20.6	297.4	480.3	23.3	3.8	M. *incognita*	臺中大肚	蕃薯
金蘭	15.0	12.3	90.1	307.2	24.9	3.1	M. *incognita*	雲林褒忠	蘿蔔
金蘭	22.2	40.7	298.0	643.1	15.8	4.0	M. *incognita*	臺中烏日	玉米
小鳳	20.4	22.6	373.2	812.3	35.9	4.0	M. *incognita*	臺南山上	蕃薯
金蘭	19.6	30.5	470.0	600.4	19.6	4.0	M. *incognita* M. *javanica*	臺南新化	蕃薯
富寶2號	17.5	20.7	298.4	121.7	54.1	4.0	M. *incognita*	臺南安南	蕃茄
金蘭	11.2	17.0	85.4	370.0	21.7	4.0	M. *incognita*	臺南大內	胡麻
金蘭	9.4	17.2	190.5	296.9	17.2	2.6	M. *incognita*	南投大坪頂	辣椒
富寶2號	30.1	26.4	320.4	81.4	10.6	1.9	M. *incognita*	嘉義北港	青椒
富寶2號	40.6	31.0	477.0	906.5	29.2	4.0	M. *incognita*	花蓮吉安	青椒

本省蔗園常發現甘蔗根部受根瘤線蟲感染，在蔗田種植西瓜後，根瘤線蟲族群大為增加，除臺中縣后里之線蟲數較低外，臺南、高雄及花蓮等縣市者皆高，線蟲種類以 M. *incognita* 為多(表二)。

表二、臺灣蔗田西瓜園根瘤線蟲之發生

Table 2. *Meloidogyne* spp. found parasitizing on watermelon in sugarcane fields of Taiwan

西瓜品種 Variety	線蟲數目／100克根圈土 No. of nematodes/100 g.soil 植前 Pre-plant	植後(月) post-plant (month) 1	3	5	R factor Pf/Pi	根瘤指數 Root-knot index	線蟲種類 Meloidogyne spieces	栽培地點 Locality
富寶2號	36.3	50.0	470.6	450.0	9.0	4.0	M. *incognita*	花蓮光復
富寶2號	40.8	62.3	443.2	515.1	8.2	4.0	M. *incognita*	臺南新化
金　蘭	25.6	30.0	375.2	647.2	21.5	4.0	M. *incognita*	高雄燕巢
金　蘭	36.3	41.2	450.0	932.4	22.6	4.0	M. *incognita*	臺南後壁
金　蘭	26.4	29.8	116.2	305.9	10.2	3.2	M. *incognita*	臺南白河
種田二號	27.6	29.7	130.4	198.3	6.6	2.1	M. *incognita*	雲林水林
種田二號	14.5	20.4	213.5	305.2	14.9	2.3	M. *incognita*	花蓮壽豐
小　鳳	26.7	30.7	240.0	213.5	6.9	1.8	M. *incognita*	臺中后里

西瓜根瘤線蟲在河床地西瓜園內，植前之線蟲數甚低，植後快速增加，線蟲種類有 M. *incognita* 和 M. *javanica* 兩種（表三）。

表三、臺灣河床地西瓜園根瘤線蟲之發生

Table 3. *Meloidogyne* spp. found parasitizing on watermelon in river bed fields of Taiwan

西瓜品種 Variety	線蟲數目／100克根圈土 No. of nematodes/100 g.soil 植前 Pre-plant	植後(月) post-plant (month) 1	3	5	R factor Pf/Pi	根瘤指數 Root-knot index	線蟲種類 Meloidogyne spieces	栽培地點 Locality
富寶2號	3.0	25.3	217.2	1,203.3	401.0	4.0	M. *incognita*	花蓮壽豐
富寶2號	6.2	17.5	374.6	504.0	87.0	4.0	M. *incognita*	臺東太麻里
富寶2號	2.0	26.1	205.9	331.2	165.6	4.0	M. *incognita* M. *javanica*	南投信義
富寶2號	0.2	10.1	315.2	461.2	2,306.0	3.6	M. *incognita*	臺中清水
富寶2號	1.2	8.5	400.3	513.5	427.9	3.8	M. *incognita*	臺中大甲
富寶2號	14.2	11.2	211.2	264.2	18.6	3.4	M. *incognita*	臺中大肚
富寶2號	5.0	13.3	198.2	275.5	55.1	3.8	M. *incognita*	雲林西螺
富寶2號	20.9	25.3	314.4	305.4	14.6	4.0	M. *incognita*	屏東高樹
富寶2號	1.5	6.0	272.0	366.1	244.0	4.0	M. *incognita*	屏東楓港
金　蘭	9.4	8.2	196.6	582.5	61.9	4.0	M. *incognita*	臺南大內
金　蘭	19.2	20.3	271.6	202.8	10.5	3.2	M. *incognita* M. *javanica*	嘉義北港

二、接種試驗與病變過程之觀察

接種根瘤線蟲之二齡蟲60天後，處理組葉片黃化，新葉皺縮變小，生長勢衰弱，地下部的根系亦結瘤甚多，根瘤指數達 4 ，末期顏色變褐色，部份已腐爛，而對照組葉片翠綠，根系健壯，生長正常，二者有顯著之差別。

三、西瓜園根瘤線蟲族群之消長

旱田西瓜園之根瘤線蟲族群，其季節性消長曲線之高峰在 7 月至 9 月間，多季的12月至 1 月間最低（圖一）。蔗田西瓜園之根瘤線蟲族群，其高峰自 6 月至10月，爲期 4 個月，而低族群密度在 1 月至 3 月（圖二）。河床地西瓜園之根瘤線蟲族群，其消長曲線最尖，族群高峰在 7 、 8 兩個月，而在11月後明顯下降（圖三）。

四、西瓜園根瘤線蟲病、蔓割病及二者病原之複合感染之發生率

由調查結果顯示，根瘤線蟲之罹病率以河床地西瓜園之60%最高，蔗田西瓜園之57.5%次之，旱田西瓜園爲55%；蔓割病罹病率在河床地、蔗田、旱田西瓜園分別爲22%，14%，17%；另二者病原之複合感染率以河床地西瓜園之16.5%爲最高，蔗田西瓜園之11.5%次之，旱田西瓜園之11%爲最低（圖四）。

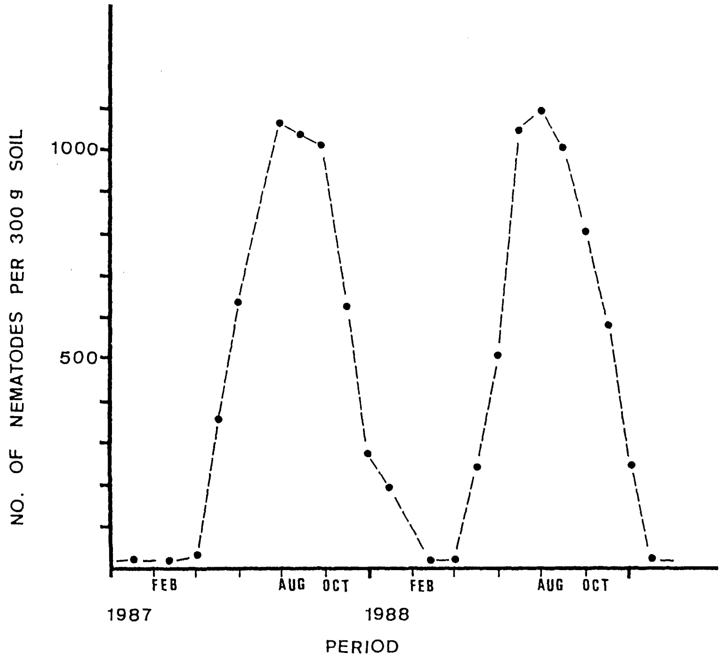

圖 1. 旱田西瓜園之根瘤線蟲之族群消長（雲林，褒忠）。

Fig 1. Population changes of root-knot nematodes in soil at the field of watermelon after upland crops.(Bau-jong, Yunlin)

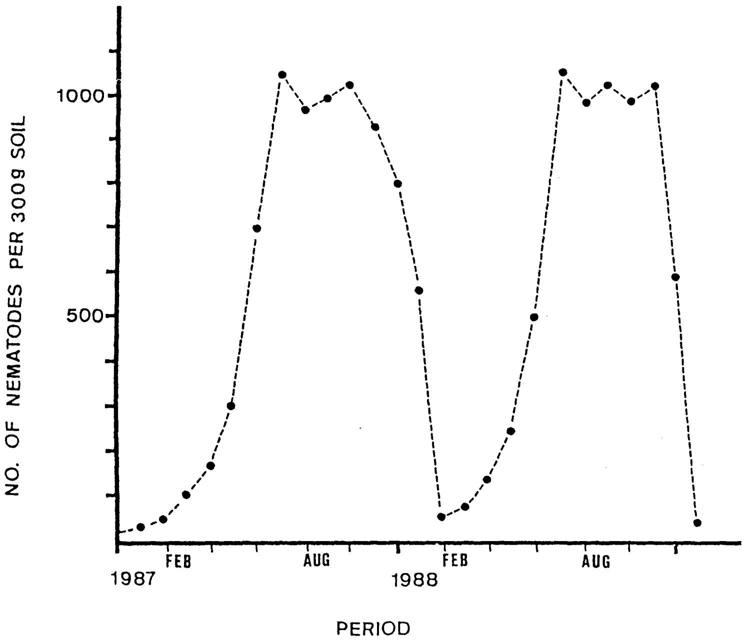

圖 2. 蔗田西瓜園之根瘤線蟲之族群消長（臺南，白河）。

Fig 2. Population changes of root-knot nematodes in soil at the field of watermelon after sugercane.(Pal-ho, Tainan)

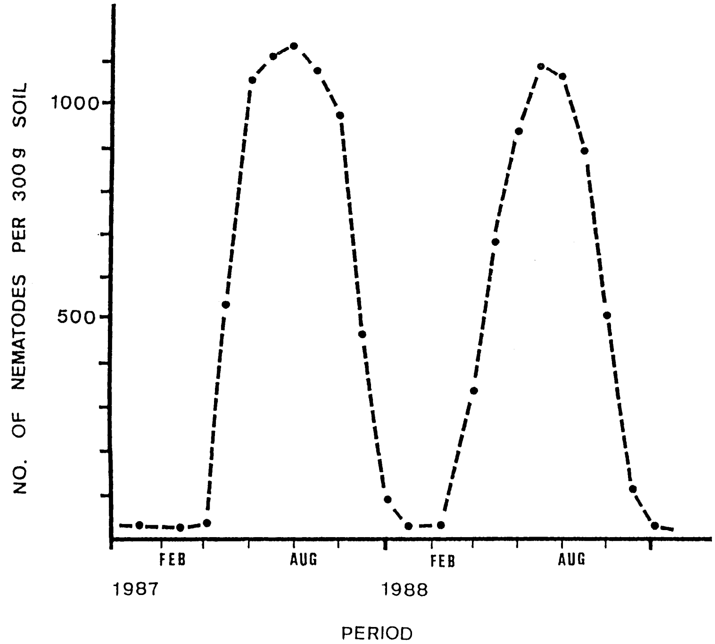

圖 3. 河床地西瓜園之根瘤線蟲之族群消長（臺中，大肚）。

Fig 3. Population changes of root-knot nematodes in soil of watermelon field at the rivebed. (Da-du, Taichung)

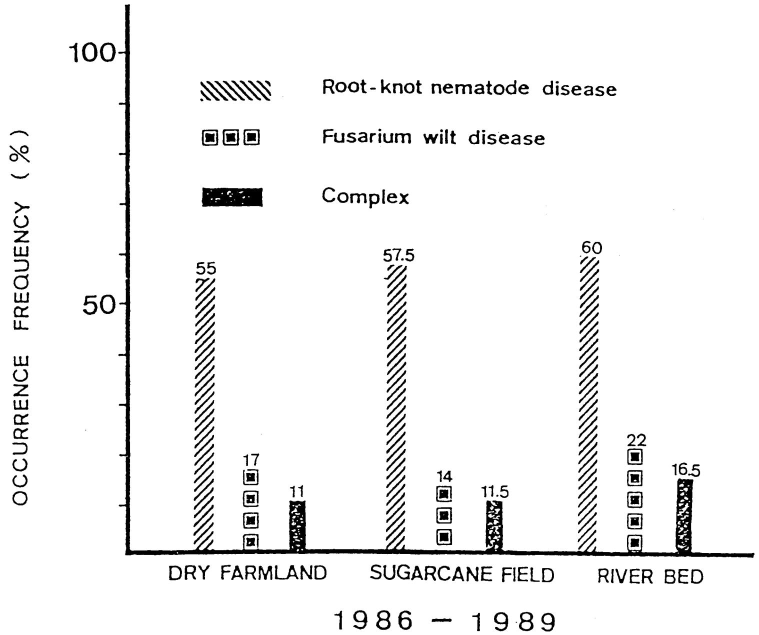

圖 4. 西瓜園根瘤線蟲病、蔓割病及二者複合感染之發生率

Fig 4. Occurrence of root-knot nematode diseases, Fusarium wilt diseases and their complexes in watermelon fields

五、土壤處理對西瓜根瘤線蟲之防治效果

溫室及田間防治試驗結果顯示，防治根瘤線蟲以施用殺線蟲劑抗蟲得、幾丁質添加物及燻蒸劑溴化甲烷為佳(圖片 2 ，3)，烏肥次之；一般有機質添加物及對照組罹線蟲病為最嚴重。而在果實品質上則以施用幾丁質添加物為最好，一般有機質添加物、烏肥及殺線蟲劑抗蟲得次之，燻蒸劑溴化甲烷者最差。產量上在各處理間以幾丁質添加物及一般有機質添加物為佳，但差異不顯著(表四、表五)。

表四、溫室中土壤處理對西瓜根瘤線蟲之防治效果

Table 4. Effect of various soil treatments on control of watermelon root-knot nematodes in greenhouse

處理 Treatment dosage/pot	根瘤線蟲數目／100克根圈土 No. of *Meloidogyne* per 100g. soil 處理前 Pre-treatment	處理後 Days after treatment 30	60	根瘤指數 Root-knot* index	瓜蔓長度(60天) Length of vine (60 days) (cm)	全株鮮重(60天) Fresh weight of whole plant (60 days) (g)
Controven 6 g	50 a	0.4 c	1.5 c	0.2 c	140.2 a	104.8 a **
Chitinous amendment 40 g	50 a	21.6 a	25.2 a	1.8 a	149.3 a	135.2 a
Common organic amendment 120 g	50 a	80.4 b	167.3 b	3.4 b	142.5 a	123.4 a
$Ca(CN)_2$ 25 g	50 a	43.7 a	40.5 a	2.3 a	139.8 a	111.4 a
CH_3Br 3 ml	50 a	0.2 c	0.5 c	0.1 c	144.5 a	108.3 a
Check	50 a	92.4 b	195.8 b	4.0 b	32.1 b	31.6 b

* Root-knot index : subjective rating 0—4; 0=no galls, 4=heavy galling

** Average of 4 replicates, numbers followed by the same letter are not significantly different, according to Duncan's multiple-range test (P=0.05)

表五、田間土壤處理對西瓜根瘤線蟲之防治效果

Table 5. Effect of various soil treatments on control of watermelon root-knot nematodes in field

處理 Treatment	根瘤線蟲數目／100克根圈土 No. of *Meloidogyne* per 100g. soil 處理前 Pre-treatment	處理後 Days after treatment 30	90	135	根瘤指數 Root-knot* index	甜度 Brix	平均果重(公斤) Fruit Mean weight (kg)
Controven 20g/plant	10.8 a	2.7 b	20.5 c	90.7 b	2.1 c	9.6 a	1.1 a **
Chitinous amendment 600kg/ha	12.0 a	8.0 b	14.7 c	69.8 b	2.0 c	11.5 a	1.8 a
Common organic amendment 2000kg/ha	11.4 a	56.2 a	250.0 a	206.8 a	4.0 a	10.0 a	1.6 a
$Ca(CN)_2$ 200kg/ha	12.4 a	17.0 b	91.2 b	180.5 a	3.2 b	10.7 a	1.2 a
CH_3Br 10 l/ha	11.8 a	0.2 c	10.8 c	131.7 b	2.8 c	9.0 b	1.0 a
Check	10.6 a	38.3 a	225.4 a	241.3 a	4.0 a	8.2 b	0.8 b

* Root-knot index : subjective rating 0—4 : 0 =no galls, 4 =heavy galling

** Average of 4 replicates, numbers followed by the same letter are not significantly different, according to Duncan's multiple-range test (P=0.05)

討　論

根瘤線蟲是西瓜栽培上主要病害之一，舉世皆然。而國外除了本省常見的南方根瘤線蟲（M. *incognita*）及爪哇根瘤線蟲（M. *javanica*）外，還有北方根瘤線蟲（M. *hapla*），曾嚴重爲害加拿大的西瓜產業[29]。1981年，Ruelo[22] 調查本省北方根瘤線蟲之寄主範圍，其中並無西瓜之記載，本調查亦未發現有該蟲爲害西瓜。此外，1979年，Orion 等[20] 亦曾報告根腐線蟲（*Pratylenchus thornei*）爲害西瓜。筆者等於本調查中亦發現西瓜園土壤中有鞘線蟲（*Hemicriconemoides* spp.）、螺旋線蟲（*Helicotylenchus* spp.）、穿根線蟲（*Hirschmanniella* spp.）、矮化線蟲（*Tylenchorhynchus* spp.）及殘根線蟲（*Trichodorus* spp.），但未發現有根腐線蟲。

根據各西瓜產地之農會資料統計，本省河床地西瓜園面積常維持在12,000公頃左右，佔西瓜總栽培面積的52%，蔗田西瓜園約6,000公頃，佔26%，而旱田西瓜園較少，約爲3,500公頃，佔15%。若以國際作物線蟲研究暨防治計劃組織（Crop Nematode Research & Control Project）公佈之瓜類罹線蟲病所造成的13.8%損失率[23]，臺灣省農林廳統計的西瓜單位面積產量[1]，和今年產地最低價格每公斤新臺幣6.4元[2]；估計本省西瓜產業每年因線蟲病害損失金額爲新臺幣二億六千三佰萬元以上，頗值得重視。

本省西瓜栽作型態大抵分爲三種：河床地連作、蔗田輪作及旱田輪作。普遍有罹根瘤線蟲病之現象，其中以河床地連作發生率較高，蔗田輪作及旱田輪作次之。旱田西瓜園的根瘤線蟲族群消長常和土壤性狀、耕作制度及作物種類有關。而本省西瓜農多年耕作習慣下，排水良好的西瓜園常和茄科作物或甘薯輪作，而上述作物也是根瘤線蟲之寄主，另西瓜園中常見的雜草，如龍葵、馬齒莧和小葉灰翟等，亦是其寄主[8]，故線蟲族群密度不易降低。如果和非南方根瘤線蟲和爪哇根瘤線蟲寄主的作物（如花生）或拮抗植物等輪作，相信有助於降低西瓜園植前線蟲密度。蔗田西瓜園根瘤線蟲病的發生一直很嚴重，主要由於蔗作利潤低，農友少用有機肥，一般只使用糖業公司配給之化學肥料，是以線蟲種類及密度都較別作物多。胡和朱氏[4]（1959）曾報告本省蔗田中常見的線蟲有15種以上，其中，根瘤線蟲之檢出率高達62%，甘蔗根部之被害率則可達90%以上。可見蔗田西瓜園，植前根瘤線蟲已普遍存在土壤中，俟感受性高的西瓜植株種植後即可侵入爲害。河床地西瓜園，植前之根瘤線蟲族群密度甚低，但因土壤質地多爲砂質地，有利於線蟲之產卵及移行，故使線蟲病易於蔓延。加上農友在河床地種植西瓜時，習慣加倍使用基肥，造成植株生長初期根系旺盛，有利於根瘤線蟲營養來源的取得，繁殖率亦高。河床地西瓜植株在罹患根瘤線蟲後，根瘤在採果期結束後大都不易腐敗，有助於此線蟲殘存期間的延長。

佔本省西瓜栽培面積半數以上的河床地，其罹根瘤線蟲與蔓割病比率均較蔗田西瓜園和旱田西瓜園爲高。探究其原因可能和農友耕作習慣種苗來源有關。本省河床地西瓜農多採大規模遊牧式耕作形態，不論該栽培地是否年年遭河水淹沒過，一年一作，且於西瓜採收後，留置殘株，並無清理田間，俟翌年瓜期再行種植。此種耕作方式甚易使蔓割病菌殘存，作爲次年感染源；又蔓割病病原菌可經由種子和種苗傳播，在土壤微生物相較單純之河床地，蔓割病發生有較嚴重之趨勢[5]。西瓜農在河床地種植西瓜前，多以每公頃300至1,000公斤的雞糞及黃豆粉等作基肥，而依 Vlk[27]（1974）的研究結果顯示，施用家畜的糞便及泥炭等，可促進線蟲的繁殖。 Rao 及 Isarel[21]（1972）發現土壤的含砂量越高，則越利於線蟲的發育及產卵。由於根瘤線蟲對西瓜有高度感受性，加上本省氣候因子、土壤條件及施肥習慣都適合本線蟲的繁殖，故促使線蟲族群密度迅速提高。蔗田土壤一般較河床地有較高黏質性，且每年蔗作後的甘蔗葉落於田中充作部份有機肥，故根瘤線蟲繁殖環境比河床地差，西瓜根瘤線蟲病發病率亦較低。旱田根瘤線蟲族群的發展往往受作物相所左右，如果西瓜的前期作是根瘤線蟲

的寄主，則土壤中線蟲族群即顯著增加，爲害到下期西瓜栽作；反之則受害率降低。但因根瘤線蟲寄主廣泛，在本省除了禾本科作物以外，旱田作物中的茄科、十字花科、葫蘆科、旋花科及錦葵科等作物都是它良好的寄主；故西瓜根瘤線蟲病之發生普遍。但由於旱田耕作頻率高，農友常施用殺蟲劑、殺線蟲劑或燻蒸劑，也因此降低根瘤線蟲發生率及爲害程度。

由田間西瓜園根瘤線蟲族的消長曲線觀之，蔗田西瓜園的線蟲族群較高，高峰期間長，此和收穫前後不加管理的雜草及不拔除殘株的習慣有關，又與土地是租賃來的，而非農民自有的心理有所關連。河床地西瓜田大抵一年一種，又因可能遭河水之淹沒，故而線蟲族群密度停留在高峰期間短。而旱田西瓜園在西瓜種植後期是根瘤線蟲族群密度最高時期，顯示瓜類在作物中是根瘤線蟲感受性較高的一類。許多文獻[10,11,13,14,17,19] 指出植物寄生性線蟲的族群密度常呈季節性消長，季節的更換包括許多環境因子的變化，諸如氣溫、雨量、日照等。而直接和線蟲族群有關的，爲寄主植物根系的生長程度。就西瓜根瘤線蟲在旱田、蔗田及河床地西瓜園的族群消長而言，每個高峰期都在西瓜植後，低峰都在田間無作物期，其間關係甚爲明顯。

本省西瓜蔓割病發生甚普遍，據黃等[7]，民國 59 年調查本省中部及北部西瓜蔓割病發生率爲 31.9%至33.4%，又孫等[5] 民國66年調查本省蔓割病發生率爲 4 %至63.2%，其中以連作田爲甚。早在1957年，Jenkins 及 Coursen[16] 即發現對由 *Fusarium lycopersici* Sacc. 引起萎凋病有免疫力之蕃茄品種，因根瘤線蟲之存在而失去免疫力。 Martin 等[18] (1955) 曾就 *M. acrita, Tylenchorhynchus* spp., *Helicotylenchus* spp. 及 *Trichordorus* spp.等四種線蟲與棉花萎凋病（*F. oxysporum* f. sp. *vasinfectum*）發生之關係作研究，結果顯示根瘤線蟲不但增加萎凋病發生率，又因其侵入寄主植物造成傷口，導致其他病原的侵入，使抗病植物失去或降低抗病性，感病植物罹病更嚴重。本省的西瓜雖一部份以扁蒲稼接，但因扁蒲亦爲根瘤線蟲之良好寄主，可能因本蟲的侵害而助長蔓割病之發生，複合感染在河床地西瓜園達16.5%，較其他栽培區爲多（圖四），似與此原因有關。

根瘤線蟲之防治上，施用系統性殺線蟲劑抗蟲得，和植前以溴化甲烷燻蒸處理及施用蝦蟹殼製成的幾丁質添加物爲佳，但在果實品質及產量上，則以後者爲佳；可見線蟲防治後，如果能同時有補充養份，則有助於植株生長勢之回復及果實品質、產量的增加。因幾丁質添加物在土壤有增加幾丁質溶解放射菌類（Chitinolytic actinomycetes）之效果，具破壞線蟲卵殼中的幾丁質層（Chitinous layer）的作用，而抑制二齡幼蟲之孵化，使線蟲族群因而可降低[24]。一般有機質肥料的添加有助於植株的生育，但若要達到抑制線蟲族群密度則須連續施用若干年，抑制效果方顯著[12]。有機肥的施用雖可促進植物生長，根系發育，卻因根瘤線蟲營養來源的大量增加，族群密度大爲提高。但 Taylor 與 Sasser[26] (1978) 認爲植物體之耐線蟲能力，須視植株被害根之罹病程度及新生根活力旺盛與否來作決定。本研究施用有機肥西瓜株，生長旺盛，在採果期才出現根系結瘤現象，但甜度及產量仍較以殺線蟲劑施用植株爲佳。若與對照組相較，雖線蟲族群密度差異不大，但植株生長勢、結果量及果實品質則差異顯著。

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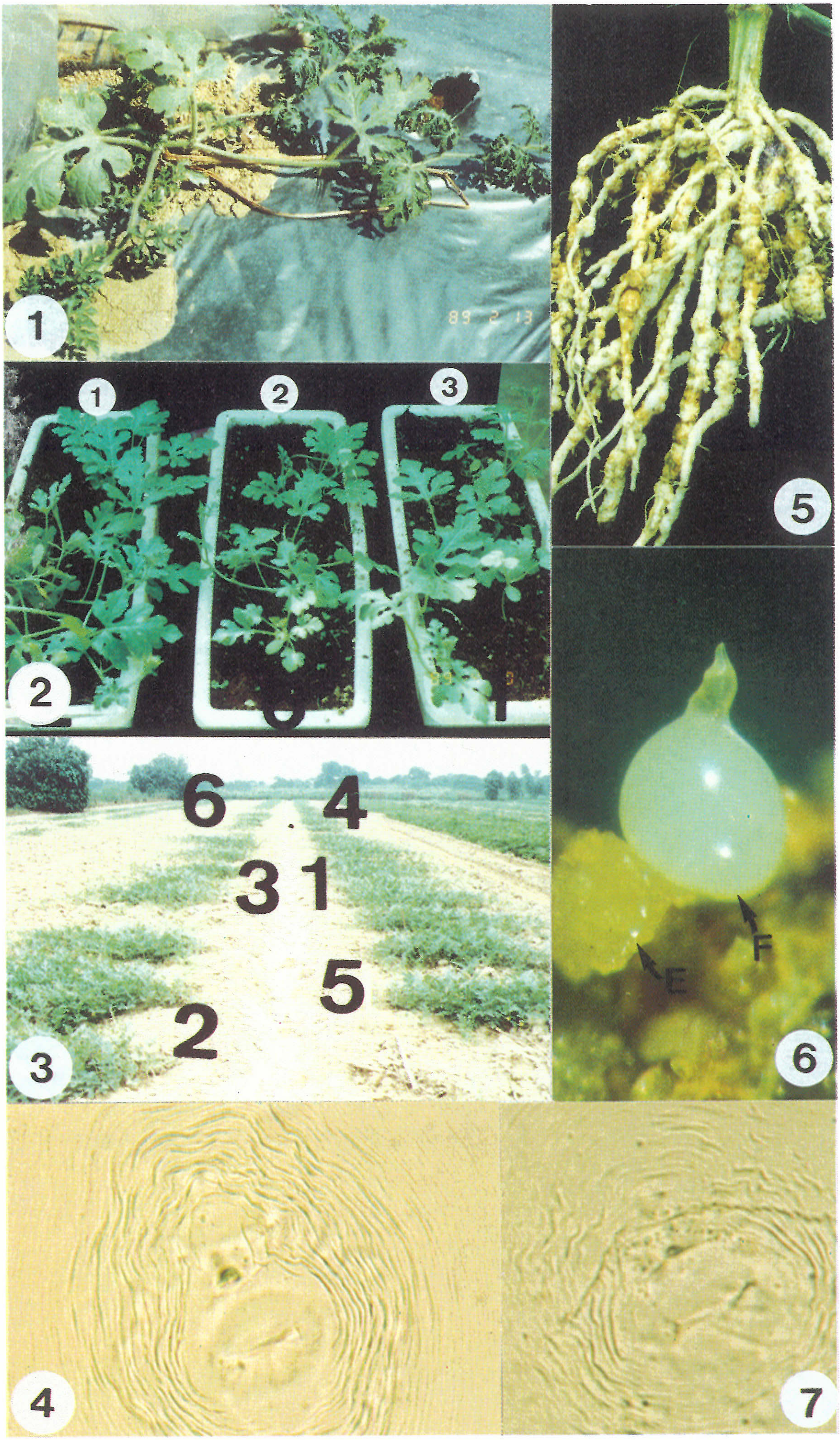
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圖片說明：

1. 田間西瓜罹根瘤線蟲病株之病徵
2. 溫室盆栽防治試驗顯示處理間之生長差異(1)幾丁質添加物(2)對照組(3)抗蟲得
3. 田間防治試驗顯示處理間之生長差異（烏日試驗區）(1)抗蟲得(2)幾丁質添加物(3)一般有機質添加物(4)烏肥(5)溴化甲烷(6)對照區
4. 西瓜南方根瘤線蟲之陰門模紋
5. 罹根瘤線蟲病之西瓜根系，結瘤纍纍，伸展不良
6. 西瓜根瘤線蟲之成熟雌蟲與卵塊
7. 西瓜爪哇根瘤線蟲之陰門模紋

Photography expression :

1. Symptoms on watermelon plant infected by root-knot nematode.
2. The difference of watermelon growth among treatments (1) Chitinous amendment (2) Check (3) Controven under greenhouse test.
3. The difference of watermelon growth among treatments (1) Controven (2) Chitinous amendment (3) Common organic amendment (4) $Ca(CN)_2$ (5) CH_3Br (6) Check at Wu-zou test.
4. The perineal pattern of adult female of *Meloidogune incognita*.
5. Root-system of watermelon infected by root-knot nematode showing galling, and extension inhibited.
6. The adult female (F) and egg mass (E) of root-knot nematode on the roots of watermelon.
7. The perineal pattern of adult female of *Meloidogyne javanica*.

The Occurrence of Watermelon Root-knot Nematode and its Control in Taiwan[1]

C. C. Tu[2], Y. H. Cheng[3], K. M. Wang[2], T. T. Tsay[4]

Summary

There are three kinds of cultural practices of watermelon in Taiwan, such as upland rotaion, sugarcane field rotation, and river bed continuous culture. The occurrence frequencies of root-knot nematodes among the different cultural types were 55%, 57.5%, and 60%, respectively. The main nematode species were *Meloidogyne incognita,* and *M. javanica*.

The peak of populations of root-knot nematodes was from July to September at the watermelon fields of uplands, and the lower population was between December and January. But at sugarcane field rotations, the climax of population was from June to October, on the other hand, the population-change curve was the sharpest at the watermelon fields of river beds. Its peak was between July and August, the population decreased obviously from November.

Under field investigation, it revealed that the complex ratio of root-knot nematode and Fusarium wilt was 16.5, 11.5, and 11% in river beds, sugarcane fields, and uplands, respectively.

The field control tests indicated that chitinous amendment, 10% Controven G., and CH_3Br obtained satisfactory effects. Their root-knot indexes were 2.0, 2.1, and 2.8 respectively with significant difference to check plot. Chitinous amendment got the best quality of fruit. Its average brix was 11.5. Of all treatments, Chitinous amendment and common organic amendment treatments showed the largest fruit quantity, but there were no significant differences among them according to statistical analysis.

Key Words : watermelon. root-kont nematode, population change, chitinous amendment, nematicide.

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1. Contribution No. 1539 from Taiwan Agricultural Research Institute.
2. Director and Assistant, respectively, Department of Plant Pathology, TARI, Wufeng, Taiwan, R. O. C.
3. Senior Plant Pathologist and Director, Chia-yi Agricultural Expriment Station, TARI, Chia-yi, Taiwan, R.O.C.
4. Assistant Professor, Department of Plant Pathology, National Chung Hsing University, Taichung, Taiwan, R. O. C.

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Dissipation of Oxytetracycline Residue in Royal Jelly[1]

C. S. Chiu[2] and L. K. Chu[3]

Abstract : Oxytetracycline (OTC) in royal jelly can be extracted by organic solvents and Amberlite XAD-2 resine column chromotography, and the average of OTC recovery was 64.86±6.14%. The cylinder-plate method is generally used for the assay of OTC residue with *Bacillus cereus* var. *mycoides* (ATCC 11778). Different dosages of OTC were applied to honeybee colonies to control foulbrood. The dissipation curves of OTC residue were achieved by periodically detecting samples of royal jelly. The curve showed that the OTC residue reduced to about 10% of initial residual level within 13 days (4 samplings). After then, the OTC residue dissipated slowly to undetectable level. For hives received 200 ppm (0.125 g) OTC twice, 100 ppm (0.063 g) twice and 50 ppm (0.031 g) once, the periods needed for residual dissiption to lower than 0.05 ppm were 45, 35 and 24 days, respectively.

Key Words : Oxytetracycline, Royal jelly, Residual dissipation.

Introduction

The royal jelly contains 66.05% water, 12.34% proteins, 5.46% lipids, 12.49% sugars, 0.82% dust and 2.84% unknown compounds (Melampy and Jones, 1939). The major lipid component, 10-hydroxy-2-decenoic acid (10-HDA), which easily dissolves in ethyl ether, has been proved as a natural antibiotic in royal jelly (Blum et al., 1959; Dixon and Shuel, 1978; McCleskey and Melampy, 1939). 10-HDA is also the major interference factor in the bioassay of oxytetracycline (OTC) residue.

OTC inhibits protein synthesis in bacteria (Suarez and Nathans, 1965). The bee keepers usually apply this compound on bee hive to prevent the infection of American and European foulbroods, however, this control method always results in antibiotic residue in bee products.

Since OTC is highly soluble in water but not in ethyl ether (Anonymous, 1968), it is easy to separate OTC and 10-HDA into different phases. The cylinder-plate method (Grove and Randall, 1969) is commonly used for the assay of antibiotic residue in food (Anonymous, 1980). To monitor OTC residue periodically and to find out its dissipation patterns in royal jelly, it is necessary to set up a standard bioassay method to analyze the amount of OTC in royal jelly.

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1. Contribution No. 1540 from the Taiwan Agricultural Research Institute.
2. Research assistant, Department of Applied Zoology, TARI, Wufeng, Taichung Hsien, Taiwan 40301, ROC.
3. Entomolgist, Department of Plant Pathology and Entomology, National Taiwan University, Taipei, Taiwan 10765, ROC.

Materials and Methods

Sample preparation

The honey bees, *Apis mellifera* L. were reared at the apiary in Taipei to produce royal jelly.

Three dosages of OTC at 0.5, 1.0 and 2.0g were dissolved in 10 liter of saturated sugar solution (1 kg sugar/1 liter water) and the concentration were 50, 100, 200 ppm, respectively. Each cocktail was then divided into sixteen equal portions for hive treatment, therefore, the dosages of OTC per hive were 0.031g, 0.063g, 0.125 g, respectively. For each treatment, royal jelly randomly collected from 5 hives with the same treatment were mixed as a sample. Three replications were conducted for each dose treatment.

Those hives treated with 50 ppm of OTC once served as the protective application. Two other doses were applied twice, and the second application was carried out on the third day, right after the first sampling. The royal jelly from treated hives were collected twice a week. The samples collected at the 3rd, 6th, 13th, 24th, 31st, 38th and 45th day after the first application were subjected for OTC residue assay.

Extraction and clean-up of OTC residue from royal jelly

The analytical procedures for tetracyclines were listed in scheme 1 (Chung, 1985, personal communication). Ten grams of royal jelly was suspended and centrifuged (1500 × g) with two subsequent volumes (50 ml and 40 ml) of 2% trichloroacetic acid solution. Half of the combined supernatant was transferred into separatory funnel and extracted with 100 ml of ethyl ether first, then 100 ml of n-hexane was added. The pH of water layer was adjusted to 5.0 before loading on XAD-2 column. The sample was eluted at the speed of 36 ml/hr, and 100 ml of distilled water was then used to elute the contaminates at the speed of 60 ml/hr. Finally, 100 ml of methanol was applied at the speed of 60 ml/hr to wash out OTC.

The methanol elution was divided into two equal portions and were concentrated into dryness with rotary evaporator. One portion of the elute was resuspended with 0.1 M phosphate buffer (pH 8.0) to the initial volume (1.8 ml) of the sample. The solution was heated on 100°C water bath for one hour to breakdown OTC and served as the check to identify other interference. The other portion was resuspended by 0.1 M phosphate buffer (pH 4.5) and used for microbioautography and cylinder-plate assay.

Preparation of OTC standard solution

The OTC standard solution (1000 ppm) was prepared by dissolving 52.8 mg OTC (94.7 % W/W) purchased from Sigma Co. in 50 ml of 0.01 N HCl solution and was divided into fifty equal portions and then stored at −10°C. The solution for testing calibration curve was diluted from this standard solution.

Mass rearing of tested organism

Bacillus cereus var. *mycoides* (BCM, ATCC 11778) was adopted as the testing organism. Colonies were periodically transferred to new slant medium (DIFCO antibiotic medium # 1) to maintain the strain.

Scheme 1. Analytical procedures for detecting oxytetracycline residue in royal jelly

For mass production, colonies of BCM were washed from slant medium by sterilized saline solution. The solution was transferred onto a layer of DIFCO antibiotoc medium # 1 in a l liter flask, and was cultured on 29°± 1°C for 14 days for sporulation. The sporulated BCM was washed out with sterilized saline solution. The mixture was repeatedly treated by heat shock, 65°C for 30 min, then 1500 x g centrifugation, till the supernatant was clear. The precipitate was resuspended with saline solution for assaying.

Assay of OTC residue

A method modified from cylinder-plate method (Grove and Randall, 1969) was adopted for assaying OTC residue, and DIFCO antibiotic medium # 8 was used to culture BCM. The test plates were prepared by pouring 5 ml basal layer medium and 5 ml seed layer medium containing BCM on a 90 mm petri dish sequentially. The steel cylinders, 6 mm inner diameter × 10 mm height, were vertically placed on the test plate, and were used as the sample holder. For the assay of OTC standard curve, five steel cylinders were placed onto each of the five test plates, then, the cylinders were applied with 0.28 ml of 0.05, 0.1, 0.2, 0.4, 0.8 ppm OTC test solutions, respectively, and cultured at 29°±1°C for 16—18 hr. The diameter of inhibition rings were measured. The standard curve was obtained by calculating these data with linear regression. Recovery of OTC can be determined with known amount of OTC in royal jelly by passing through the same extraction and clean-up procedures.

For the assay of samples, five plates each contained eight cylinders were prepared. Among these 8 cyliners, 3 of them were treated with the 3 sample solutions, another 3 of cylinders were pipetted with the same sample solutions pre-heated in 100°C water-bath. Blank buffer was added into one of the remaining cylinders, while 0.1 ppm OTC standard solution was pipetted into the other one. The interpolation method was used to propose the amount of OTC residue in samples. If the inhibition ring of heat-treated sample was smaller than that of 0.05 ppm OTC standard, it was considered to be free from contamination, and the result was acceptable. Whenever the sample inhibition ring is larger than that of 0.8 ppm OTC standard solution, it will be resampled and tested with diluted sample solution, which should fall into 0.05—0.8 ppm OTC standard range.

Bioautography

The samples were spotted on chromatographic paper (Whatman # 1, 160 x 200 mm), and developed with mixtures of n-butanol, acetic acid and H_2O (4 : 1 : 5). The developing height was 150 mm. After air-dried, the paper was then pressed against a aluminum plate (250 × 170 × 30 mm) of the DIFCO antibiotic medium # 8 containing BCM for 30 minutes. The plate medium was then cultured at 29°± 1°C for 16—18 hr. The Rf value of inhibitory zones for the OTC identification and the presence of interferences were also checked.

Results and Discussions

The Rf value of OTC residue extracted from royal jelly by paper chromatography

was 0.42, while that of the natural antibiotic (10−HDA) in royal jelly was 0.88. These compounds were easily separated and detected by bioautography. The results of bioautography and heat-treated samples demonstrated that the methods used for OTC extraction and clean-up were efficient in separating OTC from the natural antibiotic in royal jelly.

The OTC standard curve of known dose (Line I) and the extracted amount of OTC spotted into royal jelly (Line II) were presented in Figure 1. The percentage of recovery was calculated and served as a correction constant. The average recovery of OTC is 64.86 ±6.14%.

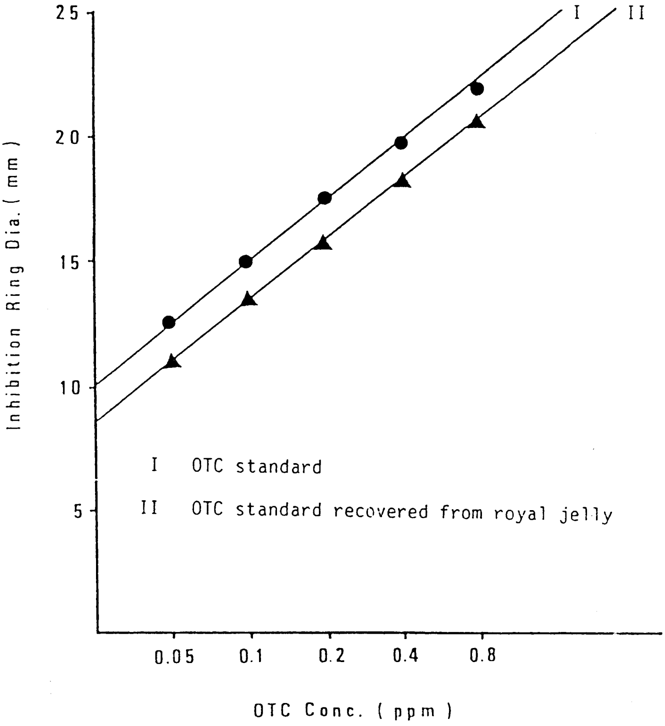

Fig 1. Comparison of OTC standard and its recovery from royal jelly.

Fig. 2 showed the dissipation patterns of OTC residue in royal jelly. For hives received 200 ppm OTC twice, the residue in royal jelly became undetectable or below 0.05 ppm after 45 days. It took 35 days for those hives applied with 100 ppm OTC twice to degrade to undetectable concentration. Twenty-four days were needed for those hives treated by 50 ppm OTC once to dissipate to undetectable level.

The persistence of OTC residue was closely related to the dosage applied to the hive. Besides, the OTC residue was much higher at the first sampling after the OTC was applied. After then, the residue reduced sharply to a comparatively low level and dissipated slowly to undetectable concentration. The high level of OTC residue in royal jelly might directly derive from sugar solution, while the slow dissipation of OTC residue might due to the contamination of OTC which was persisted in the hive.

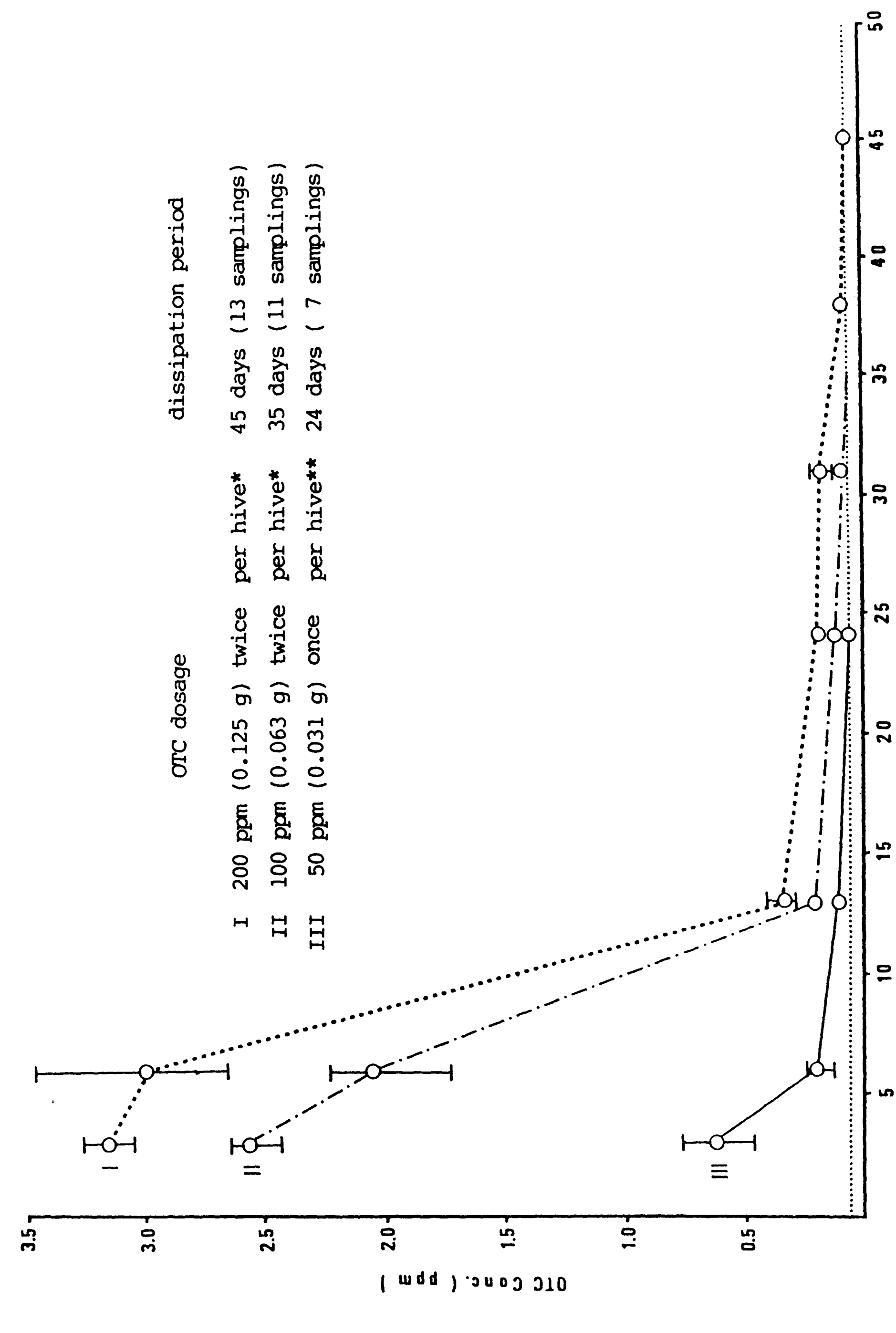

Fig 2. Decay rates of OTC residue in royal jelly
* Two applications at the 1st and 3rd day, respectively
** One application at the 1st day

Conclusions

The OTC and natural antibiotics in royal jelly can be separated due to difference of solubility in ethyl ether and water, which makes the OTC residue assay possible. By using bioautography and heat treatment, the 10-HDA contaminated sample can be easily detected. The average OTC recovery was 64.86 ±6.14%. Since the standard deviation was less than 10%, it was suggested that the procedures for OTC purification in this study were reliable.

Concentration of OTC in royal jelly reached the highest level soon after the treatments, which might directly derive from sugar solution. While the low level and slow dissipation of OTC might due to contamination of OTC that persisted in the hive. The dissipations of OTC residue were correlated to the amount of OTC that applied in hives. For hives received 200 ppm (0.125 g), 100 ppm (0.063 g) and 50 ppm (0.31 g) OTC, the periods needed for residues dissipated to undetectable level were 45, 35 and 24 days, respectively.

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蜂王乳內抗生素殘量消退之測定[1]

邱 紀 松[2]　朱 亮 光[3]

摘　要

蜂王乳內殘留之羥四環素（Oxytetracycline, 簡稱 OTC），其純化可經由乙醚的萃取，Amberlite XAD－2 之層析，再經濃縮而得。本實驗結果顯示，蜂王乳內 OTC 之平均回收率爲64.86±6.14％。其檢定，則用敏感之細菌品系，*Bicllus cereus* var. *mycoides*（ATCC 11778），以圓筒平板法（Cylinder-plate method），依所產生抑制環大小作殘量檢定。

飼育之蜂群（*Apis mellifera* L.）經分組後，分別施用不同劑量的 OTC 後，定期抽樣檢驗其蜂王乳內 OTC 殘量而得其消退曲線。曲線中顯示，在前13天內，OTC 的殘量迅速降到初次測試殘量的10％左右，此後，則以平穩而緩慢的方式消退。此消退資料可作爲訂定蜂王乳安全採收期的參考依據。

關鍵詞：羥四環素、蜂王乳、殘量消退。

1. 臺灣省農業試驗所　研究報告第 1540 號。
2. 本所應用動物系助理。臺灣省　臺中縣　霧峰鄉。
3. 國立臺灣大學植物病蟲害系博士後副研究員。臺北市。

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稻穀平衡相對濕度性質之研究[1]

陳加忠　賴建洲　曹之祖[2]

摘要：在此研究中以依序平衡相對濕度測定法量測稻穀於不同溫度下的平衡相對濕度與平衡含水率的關係。實驗中所用樣本經由55－60°C之熱風加以處理。實驗結果顯示三種 ERH 模式適用於去濕之物性。兩種模式適用於回潮之性質。在25°C和45°C時，遲滯現象並不顯著。含有四參數之 ERH 模式其對數據的適稱性並未顯著地高於含三參數的ERH模式。

關鍵詞：稻穀，平衡相對濕度模式

農產品平衡相對濕度(Equilibrium Relative Humidity, ERH)和平衡含水率(Equilibrium Moisture Content, EMC) 物性是農產加工作業研究設計上的重要影響因素。穀物在有關乾燥，貯存設備之設計必須先具備此物性資料。在特定溫度下 ERH 與 EMC 的關係曲線稱爲等溫水份線（sorption istherm）。

傳統上量測平衡相對濕度性質之方法以間接法爲主。此方法固定系統空間之相對溫度而量測平衡狀態時產品的含水率。飽和鹽溶液或不同濃度的酸液被用以產生標準的相對濕度環境。此方法簡易但受到許多限制，例如需要長時間平衡，高含水率樣本在未達平衡之前已腐敗。

爲了節省試驗所用時間，近年來直接測定法逐漸爲研究者採用。此方法是以容器裝置大量的樣本，在到達平衡狀態時，抽取樣本間隙之空氣以量取其平衡相對濕度相關值（如露點溫度，濕球溫度，水蒸氣壓…等）。但此技術受到相對濕度量測設備準確性的限制。上述兩種方法已有詳細之討論（Chen, 1989）。

近年來隨著電子技術的進步，相對濕度量測感應器的性能也日益改良。利用迴歸分析技術和良好電腦軟體的運算，相對濕度計的準確性可藉由適切迴歸校正方程式的建立而得到良好的改進（Chen, et al, 1989）。利用此方法可以使農產品平衡相對濕度的量測更爲準確，也使農產品ERH，EMC和溫度三者關係之建立更爲準確，快速。

在加工作業的設計和摸擬作業中，以簡單的數學模式代表農產品ERH，EMC，和溫度三者之關係十分重要，在衆多的模式中以包含三或四個參數的模式最常爲研究者採用，然而選擇模式適用性的比較標準並不一致。Chen（1988）曾比較評估四個包含三個參數的ERH模式在農產品物性之適用性，並用以修正研究者慣用的美國農工學會標準（ASAE, 1983)。此外，在許多乾燥和倉貯研究中所利用的ERH模式往往未曾考慮其原先模式數據之範圍，因而也未考慮外揷時對模式適用性之影響，因此利用非線性迴歸技術所得模式之外揷性能有其研究之必要。

在農產品的加工過程中，乾燥溫度對於平衡相對濕度的影響已有共同的結論，以牛肉乾(lgesias and Chirief, 1976)，玉米粒(Chen, 1988）和花生（Hung, 1989）而言，在相同的相對濕度條件下，農產品乾燥的溫度愈高，其所能吸收的水份愈少。乾燥溫度對平衡相對濕度之影響程度則因作物

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1. 臺灣省農業試驗所　研究報告 1541 號。本研究承蒙行政院國科會補助，謹此致謝。
2. 本所農機系副研究員，助理研究員，技士。

而異。

稻穀平衡相對濕度和平衡含水率在不同溫度下的關係已有許多研究，如美國Zuritz等氏（1979），澳州 Patranut 等氏（1979），日本 Kaneoka 等氏（1986）。本省稻穀在此物性之研究包含三個溫度（Chang, 1988）。在ERH的測定研究中因品種，所含成份，加工方式。和測量方法之不同，所得數據值也不盡相同，由於多數之研究方法以間接含水率測定法爲主。對於稻穀受不同乾燥溫度之影響並未加以討論。本省稻穀乾燥作業時所利用之熱風溫度範圍約於55－60°C，在此研究即以此相同溫度處理樣本，並以ERH直接測定法測定不同溫度下平衡相對濕度和平衡含水率之關係。其測定相對濕度之範圍包含10％以下與90％以上之數據。所得之數據以非線性迴歸技術比較不同ERH模式之適用性。所得的適用模式可利用於本省稻穀倉貯和乾燥作業。

理論探討

一、平衡相對濕度模式（ERH model）

爲表達在不同溫度時。平衡相對濕度與平衡含水之關係，已有許多模式被研究者提出利用。Van den Berg 與 Bruin 氏(1981)曾討論了七十七個模式。Chen(1988)檢查三十五組數據之後，發現美國農工學會所用標準修正 Henderson 式與 Chung-Pfost 式並不能適用所有農產品，修正 Halsey 式和修正 Oswin 式可適用於含高油和高蛋白質之作物。農工研究者經常利用的模式討論介紹如下：在以下的公式中 RH 代表相對濕度（小數點），M 爲含水率（％，乾基），T爲溫度（°C）。

1. Henderson 公式

此公式可說是最早被採用的公式，由 Henderson（1952）推導而得，其形式爲：

$$1-RH=Exp[-K'TM^{n}] \qquad (1)$$

Henderson氏(1952)的推導過程中有些錯誤，已由Chang氏(1988)加以更正。在公式(1) K′, n 爲常數。由於此方程式不能代表溫度的影響，因此在特定溫度時，此方程式常以如下形式表示：

$$1-RH=Exp[-KM^{n}] \qquad (2)$$

2. 修正 Henderson 公式

Thompson 等氏（1968）爲表示溫度對於 ERH/EMC 性質之影響，對於 Henderson 式（公式(1)）中溫度項內增加一常數，其形式爲：

$$1-RH=Exp[-A(T+C)M^{b}] \qquad (3)$$

在此式中，A與C值代表溫度的影響偏移（Shift），b 值則代表等溫水份線（isotherm）的形狀。

3. Day-Nelson 公式

由於 Henderson 式（公式(1)）中T並不能用以消除 K′與 n 值受溫度的影響。 Day 與 Nelson 氏（1965）將T項省略，而將 K′與 n 兩數各以溫度的乘冪數（Power function）代表，新的公式包含四個參數：

$$1-RH=Exp[-aT^{b}, M^{c\cdot T^{d}}] \qquad (4)$$

4. Kumar-Henderson 公式

在進行玉米軸，穗和粒之 ERH/EMC 性質研究時，Kumar 等氏（1978）將公式(2)之K和N值以溫度的線性函數代表，此新四參數公式爲：

$$1-RH=Exp[-(a+bT)M^{(c+dT)}] \qquad (5)$$

5. Chung-Pfost 公式

在穀物吸濕過程中水份蒸發能量的研究中，Chung 與 Pfost 氏（1967）提出如下的公式：

$$RH=Exp[\frac{A}{RT}Exp(-BM)] \tag{6}$$

R爲氣體常數，此式如同公式(1)，公式中溫度項不能代表溫度對於A, B兩常數項的影響。爲使公式(6)有更大的適用性，Pfost 等氏 (1976) 增加一個新參數而將(6)式修正如下：

$$RH=Exp[\frac{-A}{(T+C)}Exp(-BM)] \tag{7}$$

6. Chen-Clayton 公式

爲了表達溫度對公式(6)中A, B兩值之影響，Chen 與 Clayton 將M值以溫度之乘冪函數表示，其新公式爲：

$$RH=Exp[-a\ T^{b}\ Exp(-C\ T^{d}\cdot M)] \tag{8}$$

7. Oswin 公式

爲表達 ERH/EMC 等溫水份線之曲線圖形，Oswin 氏 (1986) 提出此純數學公式：

$$M=K\left(\frac{RH}{1-RH}\right)^{N} \tag{9}$$

8. 修正 Oswin 公式

原先 Oswin 公式並未考慮K與N受到溫度的影響。因此 Chen (1988) 加以修正，K值表達爲溫度的線性函數，N則與溫度不相關，新的修正 Oswin 公式如下：

$$M=(A+BT)\left(\frac{RH}{1-RH}\right)^{N} \tag{10a}$$

$$\text{或 } M=\frac{1}{\left(\frac{A+BT}{M}\right)^{c}+1},\ C=1/N \tag{10b}$$

9. Andrien-Oswin 公式

在研究小麥糊的等溫水份曲線時，Andrien 等氏 (1986) 將 Oswin 式之K與N值以溫度的線性函數代表，新公式爲：

$$M=(a+bT)\left(\frac{RH}{1-RH}\right)^{c+dT} \tag{11}$$

10.Halsey 公式

由多層水分子之概念，Halsey 氏 (1948) 推導之公式如下：

$$RH=Exp\left[\frac{A'}{RT}M^{-c}\right] \tag{12}$$

因爲 RT 項無法消除 A′ 與 C 項受溫度之影響，(12)式即被修正爲：

$$RH=Exp[-A\ M^{-c}] \tag{13}$$

11.修正 Halsey 公式

爲表達溫度與 ERH/EMC 之關係，Iglesias 與 Chirite 氏 (1976) 分析公式(13)之 A 值。而認爲其爲溫度的指數函數。新的修正 Halsey 式表達如下：

$$RH=Exp[-Exp[A+BT]M^{-c}] \tag{14}$$

在比較玉米粒四組 ERH/EMC 數據之後，Pfost 等氏 (1976) 認爲含有四個參數之 ERH/EMC 模式其適用性並不一定優於含有三個參數的模式。修正 Henderson 式與新 Chung-Pfost 式被提出以代表十四種農產品之最佳模式，並被選爲 ASAE 標準。

二、模式合適性的比較

爲比較不同方程式對於相同數據之合適性 (fitting-agreement) ，可利用於非線性迴歸的常用的判別標準介紹如下：

(一)定量標準

1. 決定係數，R^2

此值可代表公式用以說明反應值的比例。由於此值受許多因素影響，因此不能做爲良好的判別值（Myers , 1986, Helland, 1987）。

2. 估計值標準差（Standard Error of the Estimated Value, S. E.）。

S. E. 值可由殘差平方和除以自由度再加以開方而得。此值之重要意義在於此統計量與反應值有相同單位，而且可代表方程式之參數數目對於統計量之影響。

3. 平均相對離差百分比（Mean Relative Perceneage Deviation, P）

P值之計算如下：

$$P=\frac{100}{N}\sum\left|\frac{y-\hat{y}}{y}\right| \tag{15}$$

在此N爲數據數目，y爲量測值，$\hat{y}$爲方程式之預測值。雖然此值在統計原理無任何意義，但許多食品科學研究者採用此值以比較方程式之合適性（Boquet et al, 1978, Gencturk et al, 1986, Lomaaro et al, 1985）。

4. 誤差百分比平方總和之平方根

（Root Mean Square Percentage Error, RMS）

RMS值之計算式爲：

$$RMS=\left[\frac{1}{N}\sum\left(\frac{y-\hat{y}}{y}\right)^2\right]^{0.5}\cdot 100 \tag{16}$$

如同P值，此值亦無統計學上之意義，但也爲許多研究者採用（Weisser, 1985, Admrieu et al, 1986）。

(二)定性標準

對非線性迴歸的定性檢驗標準而言，繪製殘差值對預測值的分佈圖形是一種最爲有用的判別技術（Draper and Smith, 1981）。若方程式能合適的解釋數據，誤差之產生將爲任意分佈值，因此殘差圖呈現均衡的分佈關係。若方程式無法眞正的代表數據的分佈，殘差分佈將有一定的型態（Pattern）。

材料與方法

一、實驗材料

此研究中之稻穀樣本品種爲臺農67號。去濕 ERH 性質測定所用樣品以55—60℃之熱風乾燥至預設的含水率。回潮過程所需要之穀物則自極低之含水率加水調整至預設含水率。所有樣品都存置密封之塑膠容器內至少兩個月以使樣本本身因水份移轉而促使含水率成均勻狀態。爲避免樣本發霉變質，存有高含水率之樣本容器則貯存於 3 ℃之冰櫃內。

二、相對濕度感應器

此試驗所用相對濕度量測器爲 VAISALA Humidity Transmitter HMD 30UB，其主要規格如下：

a. 感應元件：HUMICAP HI0062

b. 量測範圍： 0 —100% RH

c. 20%準確度：(土) 2 %（0—90%），(土) 3 %（90—100% RH）

d. 溫度影響：以廠商所附校正式加以修正。

此感應器經校正後建立校正方程式，所讀出值經校正方程式轉換之後準確度可到達 1 %以內，此

感應器之性能評估，詳細之校正方式和校正方程式之建立已由陳氏等完成（1990）。

三、稻穀平衡相對濕度之量測

此研究採用依序相對濕度測定法（Step-by-Step ERH measurement），此方法由 Chen（1988）研究開發而成，其主要方式如圖 1 和 2 所示，將已知固定含水率之標本置於樣本容器內，濕度感應元件置於樣本之間，元件之外有保護蓋以避免與穀粒接觸而損傷。整個容器形成一密閉系統。系統在達到平衡狀態時，農產品間隙內之空氣與穀物達到溫、濕度平衡，由感應元件所量測之空氣溫濕度即代表穀物之溫度與平衡相對濕度，樣本容器置於恆溫控制箱內，在到達第一設定溫度平衡狀態時，量測記錄此溫濕度讀出值，然後調整恆溫室至下一階段溫度。在第二階段設定溫度下達到平衡之後，記錄溫濕度而再調整至第三階段設定溫度。經由此依序調整和量測方式，可在短時間內量測大量之平衡相對濕度數據，所得讀出 ERH 值再由已建立之校正方程式轉換爲眞實值。恆溫箱之穩定性爲 (±)0.1°C，又因感應元件在樣本容器內受穀物包圍且穀物本身爲熱傳之良好絕緣體，其溫度變化幅度更趨穩定，因此溫度之誤差可忽略。

此測定程序係自低溫調整至高溫。若進行自高溫調整至低溫之程序，在高含水率穀物具有高相對濕度之狀況下，由於穀物和間隙空氣熱傳係數之不同，因結露（Dew point）作用產生之水份容易滲入感應元件造成量測之嚴重誤差。

四、非線性迴歸運算

此研究中所得平衡相對濕度，平衡含水率，和溫度三者之數據以非線性迴歸技術估求其參數值和各種統計量。執行迴歸之軟體係以最小平方法和 Hartley 修正法（Hartely, 1961）爲理論依據選寫成 GW-BASIC 程式軟體。在此迴歸分析中，相對濕度爲應變値（Depentent Variables）而含水率與溫度爲獨立變數（Independent Variables）。在實驗量測過程中，含水率和溫度之數値其量

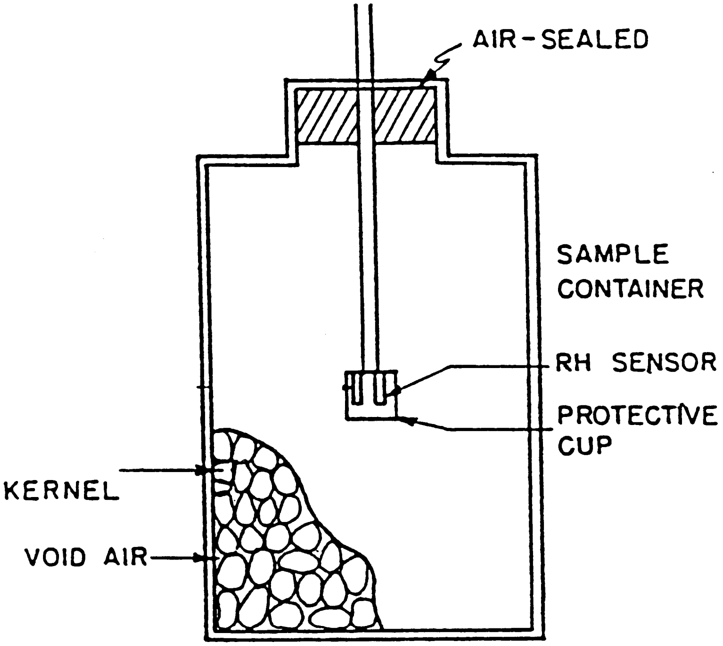


圖 1. 樣 本 容 器
Fig. 1. The sample container

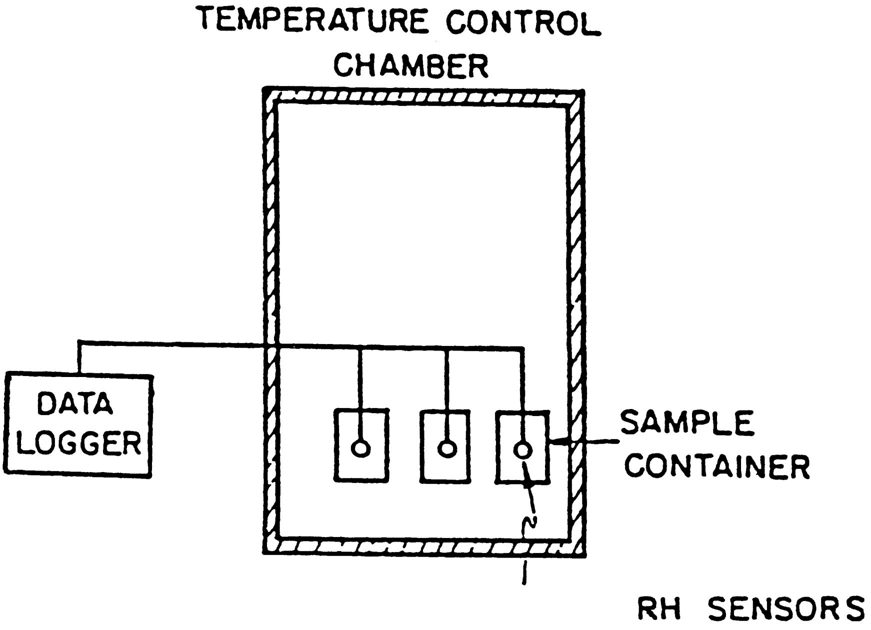


圖2. 實 驗 裝 置
Fig. 2. The experimental set-up

測誤差極小，因此符合迴歸分析之假設條件。

五、平衡相對濕度模式合適性之評估

爲比較不同相對濕度模式對於稻穀 ERH/EMC 於不同溫度下之合適性，此研究中以四個定量標準和殘差圖爲比較評估之依據。並利用美國加洲稻穀之原始數據（Zuritz et al, 1979）做爲比較。此數據之範圍如下：溫度（10, 20, 25, 30, 40°C），含水率（4.68 −22.32%），相對濕度（11.2%−86.5%）。其實驗方式係利用間接含水率測定法。

結果與討論

一、乾燥過程之 ERH/EMC 性質

稻穀在六種溫度下等溫水份線的相關數據列於表 1。由數據分佈的連續性和良好的重覆性顯示此種依序相對濕度測定法可獲得良好的實驗結果。等溫水份線爲典型的 S 型曲線（圖 3）。溫度對曲線的分佈有顯著的影響，而主要的影響範圍在於 RH 的中間範圍。

四種 ERH 模式對稻穀乾燥過程 ERH/EMC 性質的適用性比較結果列舉於表 2。四個模式迴歸分析結果的殘差圖如圖 4。

由殘差圖分佈性可知，僅修正 Halsey 公式具有明顯的分佈曲線：此公式之 P 值和 RMS 值在四個模式中最大，由此可知此修正 Halsey 式並不能適當地描述此 ERH/EMC 之分佈性質。修正 Henderson, Cnung-Pfost, 與修正 Oswin 式都具均匀分佈的殘差圖：

表 1. 稻穀之去濕數據
Table 1. Desorption data of rough rice

M. C	ERH %					
(% db)	5 °C	15°C	25°C	35°C	45°C	55°C
1.54	2.70	3.51	4.40	5.50	6.40	8.00
1.68	3.99	4.80	5.40	6.10	6.59	7.20
5.60	11.58	13.26	15.00	16.66	18.06	20.71
6.74	15.57	18.13	20.52	22.40	24.35	28.29
5.98	13.75	16.71	19.04	20.81	22.16	25.73
6.96	16.63	19.53	22.41	24.67	27.40	31.12
5.72	11.87	13.13	14.86	16.50	18.16	20.83
6.94	17.01	19.57	22.00	24.20	26.53	30.40
7.28	21.72	25.40	28.94	31.31	34.13	38.11
8.12	25.14	29.43	32.77	35.28	38.50	42.75
8.62	28.94	33.30	36.77	40.20	42.07	46.30
9.15	32.01	35.90	39.44	42.40	45.40	49.70
10.10	39.63	42.80	46.47	49.49	52.45	57.50
10.30	41.40	45.20	48.70	51.30	54.60	59.80
12.76	49.80	55.10	59.60	63.40	68.20	73.30
13.81	62.80	67.30	70.50	73.20	76.10	79.20
14.68	70.20	74.56	77.76	80.42	82.08	84.60
15.98	76.20	80.10	82.30	83.80	84.60	86.40
33.07	90.80	91.70	92.50	92.50	94.60	97.80
30.15	93.95	94.37	94.18	94.53	94.50	94.80
24.48	87.74	89.16	90.10	92.00	92.30	92.70
21.29	82.40	84.60	85.90	86.80	89.70	91.80

表 2. 稻穀去濕數據四 ERH 模式之估計參數值和比較標準
Table 2. Estimated Parameters and comparison criteria for four ERH models of desorption data for rougn rice

	Modified-Hendersion	Chung-Pfost	Modified-Oswin	Modified-Halsey
A	6.62736E-5	557.853	11.56512	4.66697
B	1.97148	0.19350	−4.8643E-2	−1.00626E-2
C	72.2045	78.3150	2.8817	2.06425
R^2	0.985	0.988	0.991	0.986
S.E.	3.772	3.316	2.957	3.622
P	12.417	10.485	13.292	16.973
RMS	22.70	19.684	29.10	33.73
Residual Plot	U.S[3]	U.S	U.S	Pattern[4]

Note : 1. ERH as the dependent variable, M and T as the indepedent variable
2. Sample dried at 55—60°C
3. U.S : Uniformly scattered points in the residual plot
4. Pattern : A systematic pattern in the residual plot

四個模式迴歸分析之 R^2 值都相當大，如修正 Halsey 之 R^2 值爲0.986。由此可知 R^2 值並不是一個判別模式合適性的好標準。修正 Oswin 方程式在四個模式中有最大的 R^2 值和最小的 S. E. 值。然而其 P 和 RMS 值則大於修正 Henderson 和 Chung-Pfst 模式。由此可知 S. E., P, RMS 值在用以比較模式的合適性時，並不一定都具有完全相同的大小次序。對 P 和 RMS 值而言，同樣大小的誤差值對反應值很小的區域（低 RH 範圍）其影響力遠大於反應值高（高 RH 範圍）的區域，由此可知若只用單一的定量標準以評估模式的合適性並不合理。

以修正 Henderson 之迴歸模式建立所得的曲線和量測數據之比較如圖 3 所示。曲線分佈與數據之符合性顯示此模式具有良好的適稱能力。

爲比較溫度和數據分佈範圍對於模式合適性的影響，以部份分割（Splitting）三組數據進行迴歸的結果與原先所有數據的迴歸結果相比較，此部份分割數據分別爲：

(A)不包含 5°C，55°C的數據。

(B)不包含15°C，45°C的數據。

(C)包含全部六溫度，但是 RH 之範圍在於（10—95%）之間。

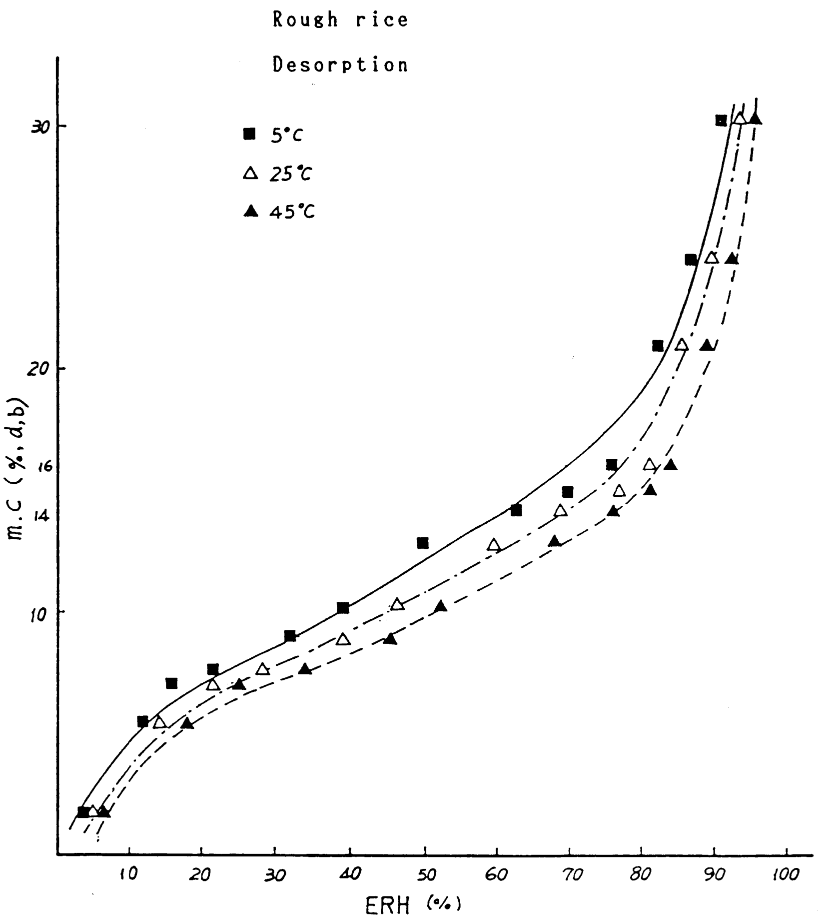


圖 3． 稻穀之去濕數據

Figure. 3. Desorption data of rough rice

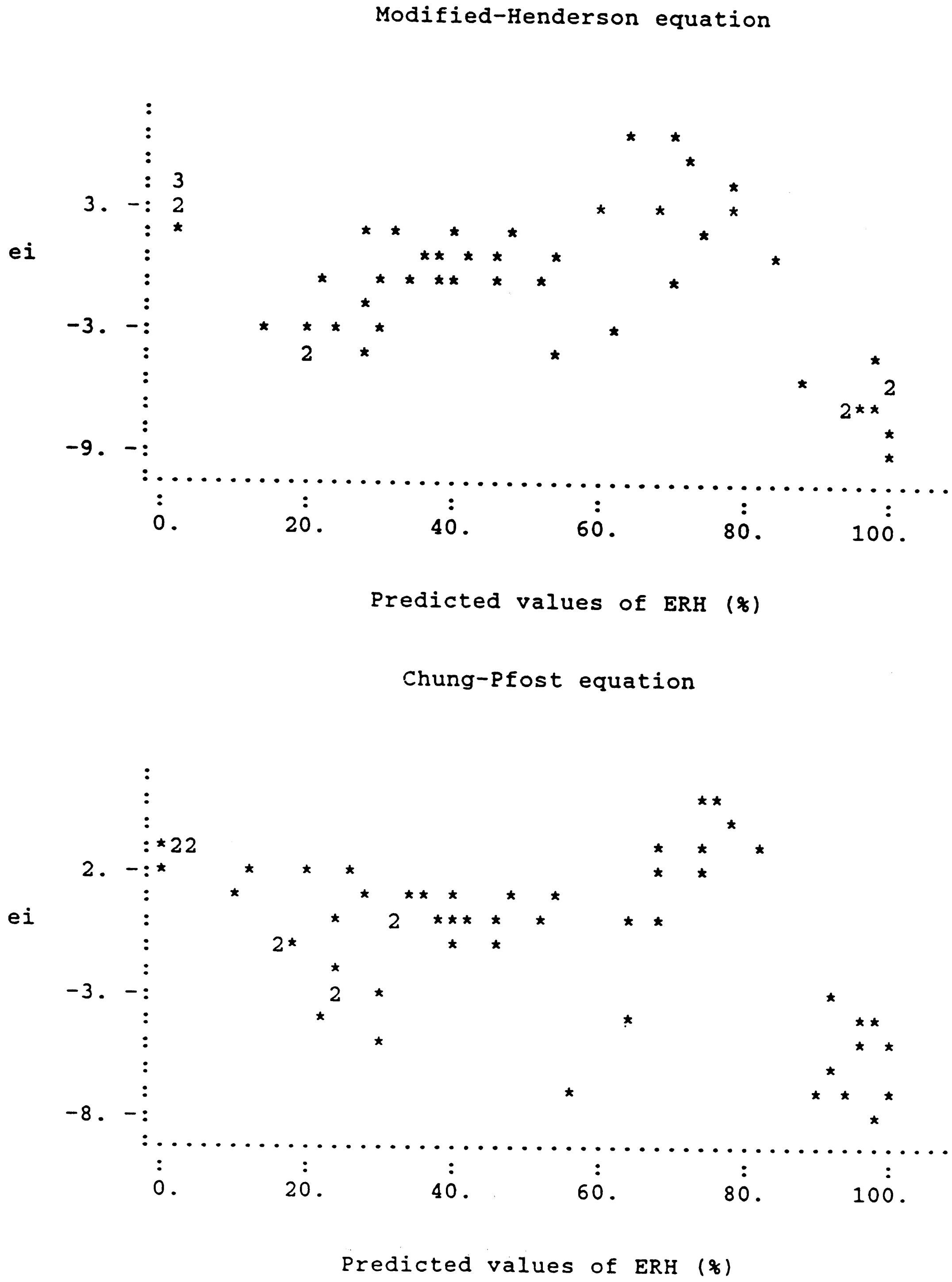
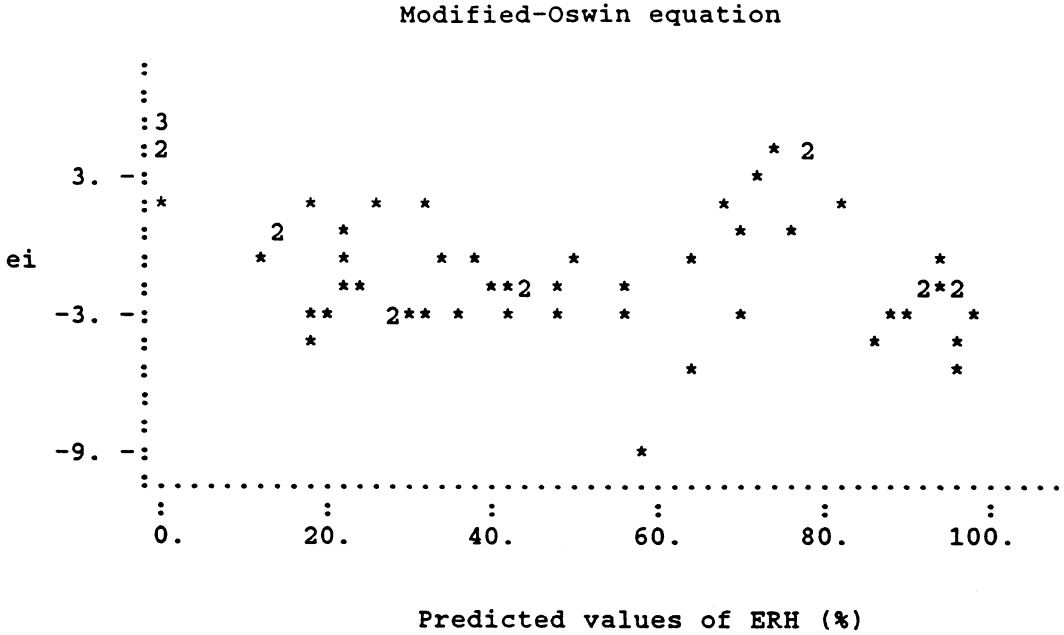


圖4a. 稻穀去濕數據 ERH 模式之殘差圖

Figure. 4a. Residuals vs. predicted values of ERH models for desorption data of rough rice



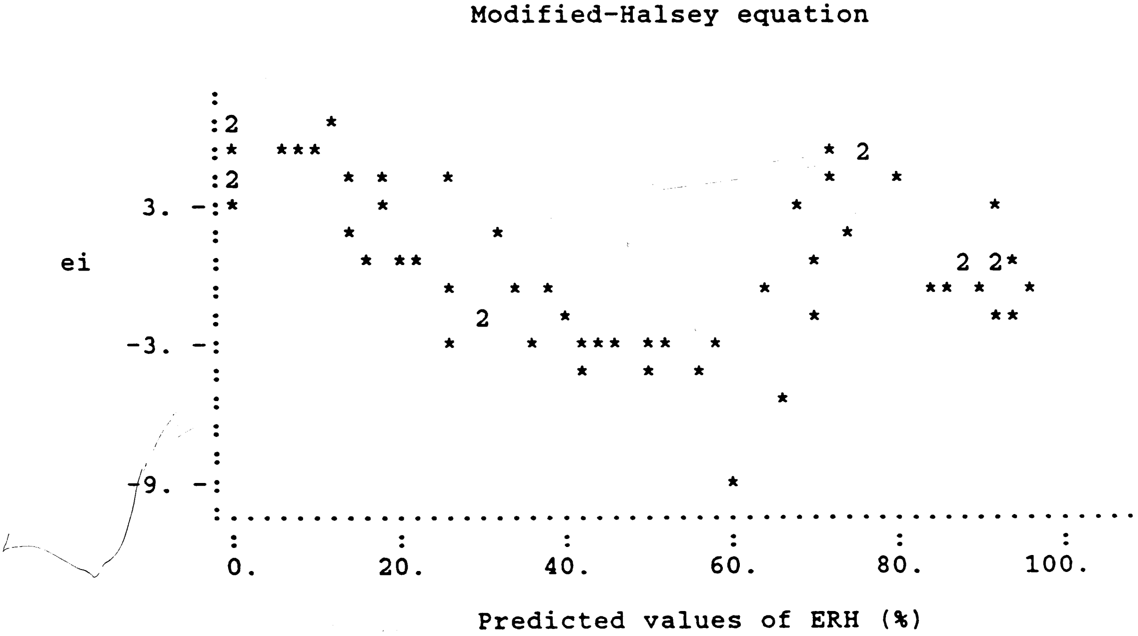


圖4b. 稻穀去濕數據 ERH 模式之殘差圖

Figure. 4b. Residuals vs. predicted values of ERH models for desorption data of rough rice

以三個 ERH 模式對於上述三組數據的迴歸結果如表 3 所示。迴歸分析結果顯示所得的新參數值（A, B 與C）與利用原來所有數據迴歸所得的參數值並無顯著的不同。統計量 P 和 S. E. 值並不受溫度範圍的影響。換言之，修正 Henderson, Chung-Pfost 與修正 Oswin 模式對稻穀ERH/EMC 性質在不同溫度範圍內插（interpolation）和外插（extrapolation）都有良好的適稱性。

表 3． 溫度與 RH 範圍對 ERH 模式估計參數值和比較標準之影響

Table 3. The effect of temperature and RH range parameters on the estimated Parameters and comparison criteria for ERH models

I. The Modified-Henderson equation

	Six Temp.	Excluded Temp 5, 55	Excluded Temp 15, 45	5—55°C 10—95% RH range
A	6.62736E-5	6.33514E-5	6.63258E-5	6.1808E-5
B	1.97148	1.9899	1.9744	2.00856
C	72.2045	71.9546	71.889	70.5067
R^2	0.985	0.984	0.984	0.984
S.E	3.772	3.798	3.813	3.48
P	12.42	12.10	12.56	5.90

II. The Chung-Pfost equaticn

	Six Temp.	Excluded Temp 5, 55	Excluded Temp 15, 45	5—55°C 10—95% RH range
A	557.853	552.125	539.36	585.32
B	0.1935	0.1950	0.19325	0.19842
C	78.3156	75.094	75.36	78.374
R^2	0.988	0.988	0.988	0.987
S.E	3.316	3.287	3.361	3.077
P	10.49	10.61	10.50	5.049

III. The Modified-Oswin equation

	5—55°C	Excluded 5, 55°C	Excluded 15, 45°C	5—55°C 10—95% RH range
A	11.5651	11.5957	11.8514	11.69248
B	−4.8643E-2	−0.04434	−5.28744E-2	−4.7615E-2
C	2.8817	2.90053	2.8304	2.9034
R^2	0.991	0.9910	0.9911	0.992
S.E	2.957	2.876	3.404	2.407
P	12.29	12.73	13.61	4.372

對只包括10—95% RH 範圍之 ERH/EMC 數據迴歸所得的 A，B與C參數值與利用原先所有數據所得之參數值並無顯著的差異。在統計量比較方面，P 值則顯著的減少。此原因可解釋爲在高 RH（大於95%）和低 RH（小於10%）的範圍，量測數據本身大的試驗誤差（Random error）容易發生。在實際的加工作業如乾燥，倉貯等，10—95% RH 的測定範圍已足以符合實際需要。此外，在極低 RH 的範圍下，EMC/ERH 觀念已不適用於乾燥過程（Chen，1988）。由此可知上述三個模式皆可適用以代表稻穀去濕過程的 ERH/EMC 關係。

二、吸濕（回潮）過程之 ERH/EMC 性質

稻穀在五個溫度下的吸濕等溫水份線其量測數據如表 4 所示。四個 ERH 模式對此組數據的迴歸參數估計和比較統計量列於表 5。由殘差圖分佈之檢驗方式可知修正 Oswin 模式和修正 Halsey 模式都具有特定的曲線趨向，此現象表示兩模式並不適用於這些數據。

表 4. 稻穀之去濕數據
Table 4. The adsorption data of rough rice

M. C	ERH %				
(% db)	5°C	15°C	25°C	35°C	45°C
2.85	7.49	8.50	9.75	10.39	11.26
3.55	7.76	8.51	9.82	10.57	11.37
4.12	8.36	10.71	11.62	13.28	14.86
4.65	12.22	12.83	14.69	16.01	17.50
7.36	21.30	24.10	28.30	30.11	31.97
8.24	21.66	25.18	29.77	32.98	35.36
9.19	29.93	34.11	37.95	40.08	42.62
9.25	30.40	34.13	37.64	40.42	43.63
9.91	36.20	40.65	44.53	46.83	48.79
9.92	37.10	41.18	44.91	47.14	49.14
12.09	47.80	52.55	56.00	59.14	60.65
14.25	58.72	63.69	67.13	71.17	71.95
14.69	60.59	64.17	66.92	69.59	70.83
15.34	68.86	72.90	75.69	78.62	79.80
17.32	77.75	80.77	82.10	84.10	84.30
17.41	79.70	83.00	84.20	85.70	86.50
18.93	85.49	87.50	88.30	89.05	89.94
21.27	90.23	91.43	91.71	92.14	92.58
21.66	90.65	91.76	92.11	92.59	92.93
27.13	88.26	89.88	91.35	93.30	95.60
26.36	90.80	90.60	90.80	92.20	92.80
25.83	89.00	89.70	90.80	92.20	93.30
23.98	90.00	90.80	90.90	91.50	92.00
23.50	92.40	93.90	93.60	94.90	95.30
23.11	87.60	88.80	90.50	91.70	92.70

表 5. 稻穀去濕數據四 ERH 模式之估計參數值和比較標準
Table 5. Estimated parameters and comparison criteria for four ERH models of adsorption data for rougn rice

	Modified-Henderson	Chung-Pfost	Modified-Oswin	Modified-Halsey
A	9.3241E-5	507.728	11.9457	5.42311
B	1.80986	0.17254	−4.7258E-2	−1.03946E-2
C	72.359	85.8474	2.7888	2.34585
R^2	0.987	0.990	0.983	0.963
S.E.	3.665	3.155	4.129	6.108
P	7.346	7.390	14.11	22.886
RMC	11.398	12.48	25.20	43.42
Residual Plot	U.S	U.S	Pattern	Pattern

修正 Henderson 與 Chung-Pfost 模式可適用以代表稻穀吸濕過程中 ERH/EMC 之關係。對兩者模式迴歸分析之統計量而言，Chung-Pfost 模式之 R^2 值較大，S. E. 值較小，但其 P 和 RMS 值則大於修正 Hnederson 公式。此再度說明統計量之比較並無一致的結論。因此可知以單一統計量做為評估模式的唯一量化標準是不可靠的。

三、遲滯效應 (Hysteresis)

由於農產品 ERH/EMC 性質受到去濕和吸濕過程所影響，此種差異性稱為遲滯效應。

在25°C吸濕和去濕過程之比較如圖 5 所示。兩者並無太大的差異，僅在高 RH 範圍，去濕數據高於回潮數據。 5 °C和45°C遲滯之現象如圖 6 所示。在 5 °C時，遲滯現象較為明顯，而45°C之環境下兩者幾乎無所差別。由此可知經熱風處理之稻穀由於其結構成份結構性改變，使遲滯效應之差異大為減少。而遲滯效應在低溫時，比高溫更明顯。此與玉米粒之 ERH 物性相同 (Chen，1988) 。

在許多乾燥和倉貯通風的模擬的模擬研究中，往往假設遲滯效應本身並無差異。對於以高溫乾燥風進行之乾燥作業或經高溫乾燥後穀物的倉貯通風作業而言，此種假設可成立。

由於農產品 ERH 性質受許多因素影響。不同品種，不同乾燥溫度對於稻穀吸濕和去濕時 ERH/EMC 性質有詳細研究之必要。

四、模式參數數目對 ERH/EMC 數據合適的影響

一、臺農67號稻穀

以此次實驗所得去濕數據對四個含有四參模式 (公式(4)，(5)，(8)，(11)) 進行非線性迴歸分

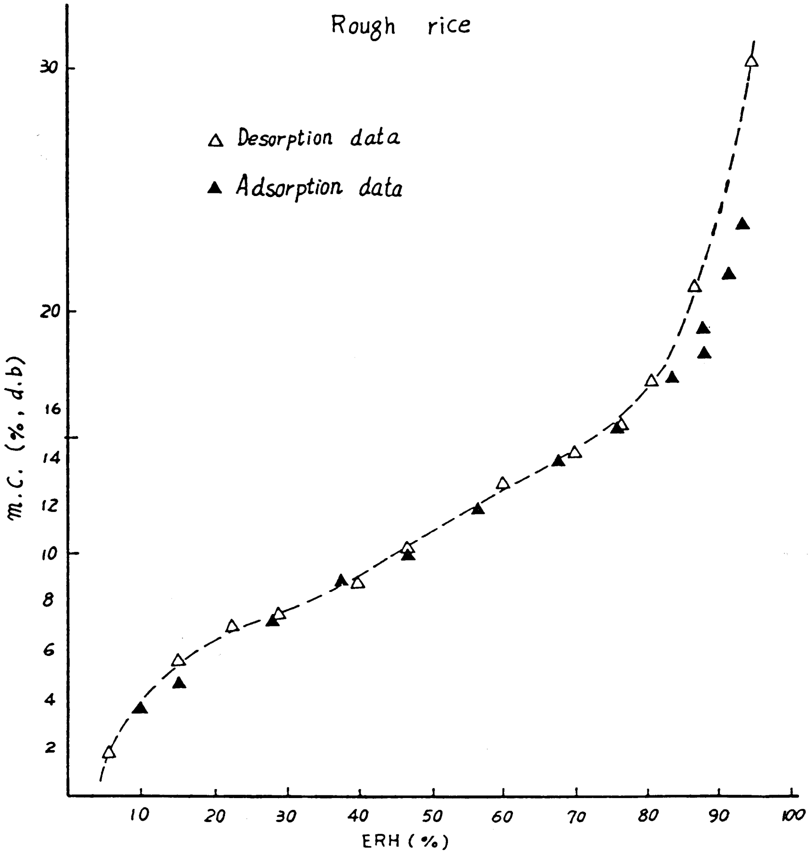


圖 5. 稻穀於25°C時吸濕與去濕數據

Fig. 5. Adsorption and desorption data of rough rice at 25°C

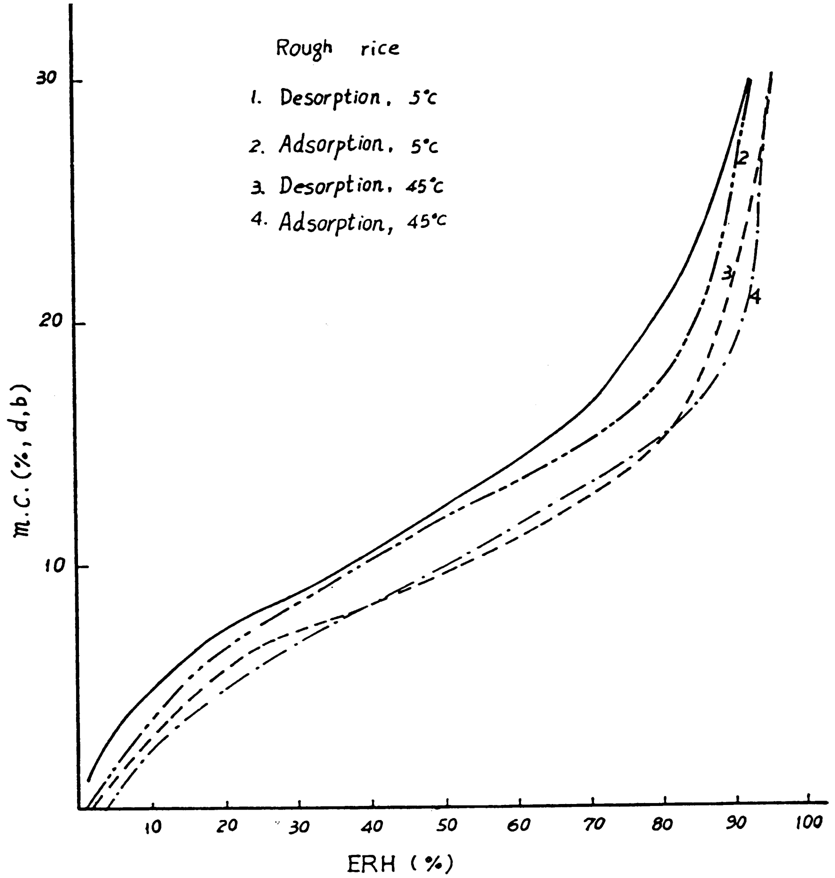


圖 6. 稻穀在兩溫度吸濕曲線之遲滯效應

Figure. 6. Hysteresis effect of sorption isotherm for rough rice at two temperatures

析，其所得參數值和統計量列於表 6 。由此結果可知，在由相同根源模式所加以修正推衍的修正模式中，含四參數的模式其合適性並未有顯著的改良 。根源於 Hnederson 公式的三模式中， Day-Nelson 模式其 R^2 值小於修正 Henderson 公式之 R^2 值，而且 S. E. 與 P 值均大於含三參數之模式，僅 RMS 值較小。對於 Kumar-Hnederson 模式而言，R^2 值與三參數之模式相同，P 值較小，但是 S. E. 與 RMS 值皆有較大值。由於 S. E. 值統計量考慮了參數數目對於統計量的影響，由此可知含四參數之模式其合適性能並未有顯著改善。

表 6. 稻穀（陳氏）去濕數據八模式適稱性之比較

Table 6. The comparison of the fitting-agreement for eight models of Chen's desorption data

Original Equation	Henderson Equation			Chung-Pfost Equation		Oswin Equation	
	Modi.-Henderson	Day-Nelson	Kumar-Henderson	Chung-Pfost	Chen-Nelson	Modi.-Oswin	Andrieu-Oswin
A (a)	6.627E-5	3.6937E-3	4.530E-3	557.85	5.8581	11.565	11.8256
B (b)	1.9715	0.4327	6.943E-3	0.1935	−3.476E-2	−4.864E-2	−5.286E-2
C (c)	72.205	1.8341	1.9842	78.31	0.1416	2.8817	0.3486
(d)		−3.716E-2	−3.6823E-5		9.05E-2		−3.410E-5
R	0.985	0.981	0.985	0.988	0.988	0.991	0.991
S.E.	3.77	5.16	3.79	3.32	3.43	2.96	2.86
P	12.42	13.96	12.26	10.49	10.93	13.29	12.86
RMS	22.70	19.70	22.78	19.68	19.68	29.10	29.07
Residual Plot	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.

對導源於 Chung-Pfost 公式之兩修正式，含四參數的 Chen-Nelson 模式其 R^2 值，RMS 值與含三參數模式之新 Chung-Pfost 修正式相等，其他統計量並未有所改良。以導源自 Oswin 模式之公式而言，四模式之 Andrien-Oswin 模式其評估統計量雖比三參數之修正 Oswin 公式較好，但未顯著性的影響。

由上述之比較可知，含四參數之修正模式對於數據的適稱性並未勝於三參數的模式。

二、美國加洲稻穀

此研究所得原始數據得自於相關文獻（Zuritz et al, 1979）。依各模式之非線性迴歸分析結果列於表 7 。

表 7． 稻穀（Zuritz）去濕數據八模式適稱性之比較

Table 7. The comparison of the fitting-agreement for eight models of Zuritz's desorption data

Original Equation	Henderson Equation			Chung-Pfost Equation		Oswin Equation	
	Modi.-Henderson	Day-Nelson	Kumar-Henderson	Chung-Pfost	Chen-Nelson	Modi.-Oswin	Andrieu-Oswin
A (a)	3.5031-5	1.1290E-5	1.2384E-3	363.73	22.0613	16.036	16.6878
B (b)	2.3159	1.5609	2.2018E-3	0.1807	−0.3596	−0.1215	−0.1146
C (c)	27.407	4.04997	2.2498	26.673	0.1652	3.3671	0.2753
(d)		−0.17972	2.9164E-3		2.899E-2		1.0283E-3
R	0.993	0.994	0.993	0.993	0.990	0.989	0.991
S.E.	2.14	1.95	2.08	2.09	2.49	2.55	2.33
P	5.70	4.33	5.64	4.56	5.41	7.19	6.29
RMS	9.35	6.00	9.74	6.41	7.37	13.68	11.52
Residual Plot	U.S.	U.S.	U.S.	U.S.	U.S.	Pattern	Pattern

對於源於 Henderson 模式的三種修正模式而，Day-Nelson 模式之合適性比含三參數模式之修正 Henderson 公式其合適性較好，而 Kumar-Henderson 公式並未有所改善。但是四參數之模式其合適性之改良並不顯著。對於源於 Chung-Pfostm而言，含四參數的 Chen-Nelson 模式適合性比含三參數的新 Chung-Pfost公式更差。對於源於 Oswin 公式之修正模式而言， Andrien-Oswin 模式其適合性比三參數之修正 Oswin 式較佳，但並未俱有顯著性之改良。由此可知含四參數之模式其合適性並未勝於三參數之模式。

修正 Henderson 與 Day-Nelson 模式之殘差圖如圖 7a 所示，兩圖數據之分佈性質十分相似。Chung-Pfost 模式和 Chen-Clayton 模式之殘差圖其分佈狀況亦類似（圖 7 b）。此原因可解釋爲其根源於相同的原始模式。

由上述兩者數據各模式之合適性比較，一味增加模式中參數之數目並不代表模式之合適性即得到改善。對含三參數之模式而言（公式(3)，(7)，(10)與(14)）已可代表農產品平衡相對濕度，平衡含水率和溫度之關係。此四個模式對於各種農產品的適應性也已詳細的研究（Chen，1988）。然而，此種含有三參數的模式往往有許多誤用的情況。例如以固定溫度條件下的 ERH 對 EMC 的數據代入公式中求其 A, B, 和 C 之參數值（Genctukk. et al, 1986），此即不瞭解原來修正公式用以考慮溫度影響性的意義。而若再將此方式所得之各溫度下A，B，和 C 值以溫度爲自變數進行線性迴歸（Hutchinson and Otten, 1984，Cenkokski et al, 1989），此只是使得 ERH 模式更加複雜化，對模式之適稱性並無改善，更是未瞭解模式修正以包含溫度影響的意義。

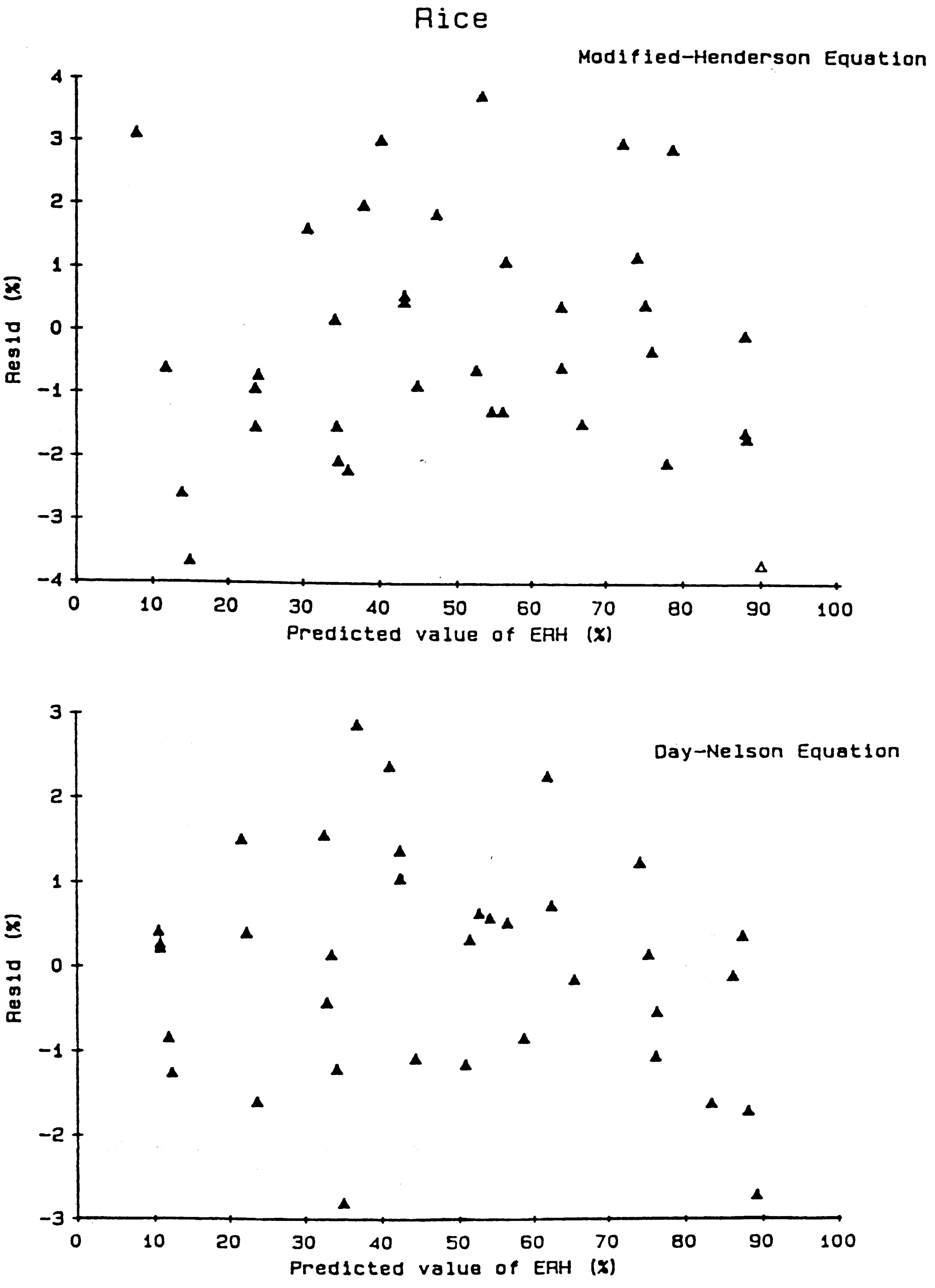


圖7a. 美國稻穀 ERH 模式之殘差圖

Figure. 7a. Residuals vs predicted values of ERH models for rough rice (U.S.A)

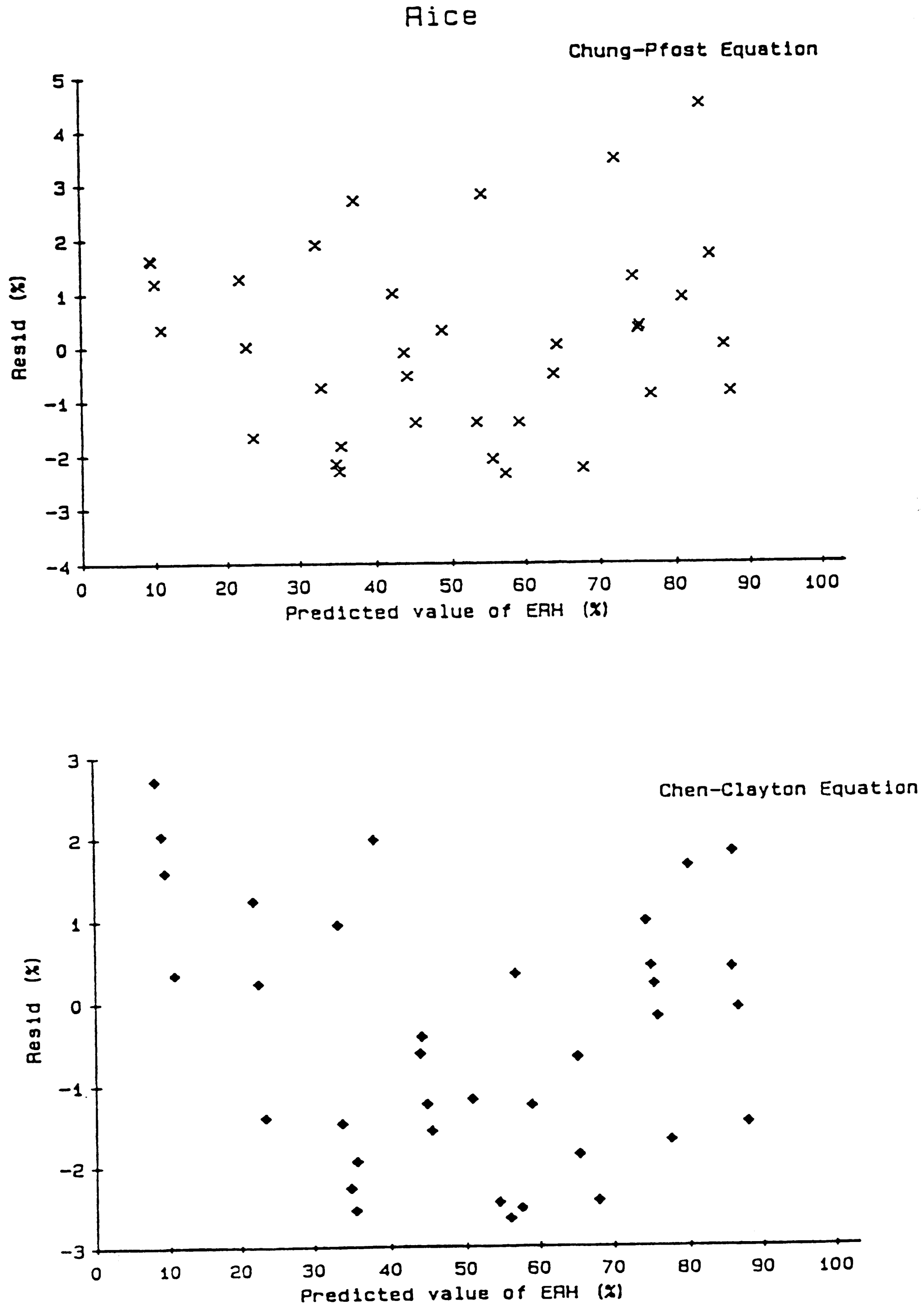


圖7b. 美國稻穀 ERH 模式之殘差圖

Figure. 7b. Residuals vs predicted values of ERH models for rough rice (U.S.A)

在此研究中只討論了非線性迴歸模式之適稱（fitting agreement）能力。至於預測能力（Prediction ability）的比較統計量如 PRESS 值或 PRESS 殘差絕對值總和值（Myers, 1986）因涉及更複雜之計算，需要更詳細之研究。

結　論

由上述研究所得之結論如下：

1. 稻穀樣本經55—60°C溫度處理至各不同含水率後所得之平衡相對濕度，平衡含水率和溫度三者數據其關係之適用模式爲修正 Henderson, Chung-Pfost, 和修正 Owsin 模式。此樣品之回潮相關數據以修正 Henderson 和 Chung-Pfost 模式爲適用模式。這些模式之參數值可做爲本省稻穀乾燥和倉貯作業之設計因子。

2. 對於 ERH 模式對稻穀數據的適用性而言，溫度值的內插或外插性能都十分良好。RH 數值範圍於10—95%時有良好的適稱性。

3. 經由高溫（55—60°C）處理後的稻穀，在25和45°C之遲滯現象並不顯著。低溫時遲滯現象較爲明顯。

4. 含四個參數之 ERH 模式其適稱能力並未顯著地優於含三參數的 ERH 模式。具有三參數的 ERH 模式已足以適用於代表稻穀平衡相對濕度，平衡含水率和溫度之關係。

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A Study of Equilibrium Relative Humidity properties for Rough Rice[1]

C. C. Chen, C. C. Lai, and C. T. Tsao[2]

Summary

The relationships of equilibrium relative humidity and equilibrium moisture content of rough rice at different temperature were measured by step-by-step ERH determinating method in this study. The sample was treated by the heated air at the range of 55-60 °C. The experimental results indicated that three ERH models can serve as good model for desorption data. Two adequate ERH models could be used for adsorption data. The hystereses was in 25 and 45°C. The fitting-agreement of four-parameter ERH models did not have better performance than those of the three-parameter ERH models.

Key words : ERH model, Rough rice.

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2. Associate researcher, Assistant researcher, Junior specialist, respectively, TARI, Taichung, R. O. C.

Jour. Agri. Res. China (中華農業研究) 39(4)：367～376 (1990)

Modification of Oswin EMC/ERH equation[1]

Chia-Chung Chen[2]

Abstract: An empirically modified Oswin equation is proposed to consider the effect of temperature on the sorption isotherms of several biolgical materials. Parameters of the sorption equations are presented. This three-parameter non-linear equation can fit the observed data adequately. It provides a simple form to describe the relation between EMC, ERH, and temperature.

Key Words: Temperature, Oswin equation.

INTRODUCTION

A number of theoretical, semi-theoretical, and empirical isotherm equations have been developed to model the relationship between EMC, or ERH, and temperature.

Empirical equations have found to be more accurate and convenient than theoretical and semi-theoretical relationships. Isotherm equations used most frequently are presented and discussed in the following section. In these equations, RH denotes relative humidity, M moisture content on dry basis, and T temperature.

1. The Henderson equation

The most widely used and best known model for the sorption isotherm of biological materials is this semi-empirical equation derived from Gibbs adsorption theory.

Henderson (1952) presented this equation:

$$1-RH=Exp(-K*T*M^{N}) \qquad (1)$$

K and N are constants, thus the equation cannot predict the correct shift of the isotherm as the temperature changes.

2. The Modified-Henderson equation

To study the simulation of corn drying, Thompson et al. (1968) modified the Henderson equation by adding another constant into the temperature term. The practical effect of the modification is to move the temperature of absolute zero to a higher temperature.

The modified equation becomes:

$$1-RH=Exp(-A*\ (T+C)*M^{B}) \qquad (2)$$

Where A, B, and C are constants.

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1. Contribution No. 1542 from Taiwan Agricultural Ressearch Institute
2. Associate researcher, respectively, TARI, Taichung, Taiwan, R. O. C.

A different modification of the Henderson equation was presented by Zuritz et al. (1979) to describe the desorption isotherms of rough rice from 10 to 40 °C.

3. The Chung-Pfost equation

Based directly upon an assumption that the way the free energy changes for sorption is related to moisture content, Chung and Pfost (1967, Part II) presented a model of the form :

$$RH=Exp(-\frac{A}{RT}Exp(-B*M)) \qquad (3)$$

Where R is the universal gas constant, and A and B are constants.

As with the Henderson equation, this equation cannot be used to predict the effect of temperature since the use of the T term does not eliminate the temperature dependence of parameters A and B.

In order to obtain a better fit, Pfost et al. (1976) added a new parameter to the temperature term and combined the R value in the constant term.

The new equation is:

$$RH=Exp(-\frac{A}{T+C}Exp(-B*M)) \qquad (4)$$

Where A, B, and C are constants.

4. The Halsey equation

Halsey (1948) developed an equation to describe the condensation of multilayers at a large distance from the surface.

The equation is:

$$RH=Exp(-\frac{A}{RT}*M^{-c}) \qquad (5)$$

Because the use of the RT term does not eliminate the temperature dependence of constants A and C, Iglesias and Chirife (1976d) simplified it to the form:

$$RH=Exp(-A*M^{-c}) \qquad (6)$$

They found this equation could be used to describe the sorption behavior of 69 food materials reasonably well.

5. The Modified-Halsey equation

In studying the effect of temperature on water sorption isotherms, Iglesias and Chirife (1976a) analyzed the parameter A of the Halsey equation (Eq. 6) and found that it could be related to temperature by an empirical expopential function. A new Modified-Halsey equation was proposed:

$$RH=Exp(-Exp(A+B*T)*M^{-c}) \qquad (7)$$

Where A, B, and C are constants.

6. The Day-Nelson equation

Because the T term in the Henderson equation does not eliminate the temperature dependence of constants K and N, Day and Nelson (1965) omitted the T term and replaced the constants with an empirical power function of temperature.

The new four-parameter equation is:

$$1-RH=Exp(-a*T^{b}*M^{cT^{d}}) \quad (8)$$

Where a, b, c, and d are constants.

7. The Chen-Clayton equation.

In order to predict the temperature dependence of the isotherm, Chen and Clayton (1971) propsed a four-parameter equation to describe the relation of moisture, temperature, and relative humidity. The model is:

$$RH=Exp(-a*T^{b}*Exp(-c*T^{d}*M) \quad (9)$$

Where a, b, c, and d are constants.

The equation is a modification of the Chung–Pfost equation (Eq. 3) with the constants A and B represented as empirical power functions of temperature.

Development of the Modified-Oswin equation

The objective of this study was to develop a simple equation for relating EMC, ERH, and temperature. A fully empirical isotherm equation with two parameters proposed by Oswin (1946) was further modified to consider the temperature effect.

Compared to the two-parameter sorption equation presented by Boquet et al. (1978), the Oswin equation was able to fit the sorption data better for protein and starchy foods. This equation is a mathematical series expansion of sigmoid shaped curves. It can be written as.

$$M=K*\left(\frac{RH}{1-RH}\right)^{N} \quad (4.43)$$

K and N are constant.

Presented by Oswin (1946), this equation primarily was adopted to solve a packaging problem. Since it is purely empirical, it received relatively little attention in the literature. Labuza et al. (1972) applied the equation to correlate EMC data in non-fat dry milk and freeze dried soluble tea. Andrieu et al. (1985) found that sorption data of Durum wheat pasta could be fitted by the Oswin equation with good precision.

Transformming into the linearized form, yields,

$$\ln M=\ln K+N*\ln(RH/1-RH) \quad (11)$$

The parameters K and N do not account for the temperature dependence.

A plot of ln M and ln (RH/(1−RH)) should be a straight line if this equation fits isotherm data well. If the parameters can be expressed as a function of temperature, then the equation can be modified to consider the temperature effect, in the same way as the Henderson equation was modified by Day and Nelson (1965), or the Chung equation by Chen and Clayton (1971).

Several original sets of isotherm data for biological materials were collected to find the parameters for the Oswin equation. The result are listed in Table 1. High R-square values strongly indicated that lnM and ln (RH/(1−RH)) had a linear relation.

Table 1. Parameters K and N for the Oswin equation

Products	Temp. (°C)	Range of RH	K	N	R-Square
Red beans (Guevara) 1963	21.1	0.12—0.80	13.4852	0.3287	0.969
	26.6	0.12—0.69	12.4578	0.3563	0.978
	32.2	0.12—0.69	12.4215	0.3761	0.976
	37.8	0.13—0.70	12.0973	0.4364	0.981
Winged beans (Ajibola) 1986a	40.0	0.12—0.82	8.9694	0.4348	0.993
	50.0	0.11—0.81	7.3550	0.4637	0.956
	60.0	0.11—0.80	6.6917	0.5373	0.967
	70.0	0.11—0.80	5.8700	0.5399	0.984
Corn (Rodriguze.) 1956	4.4	0.13—0.76	14.4950	0.3196	0.999
	15.6	0.32—0.95	12.8550	0.2817	0.997
	30.0	0.11—0.86	11.2967	0.3400	0.972
	37.8	0.11—0.97	10.6566	0.3039	0.955
	50.0	0.11—0.85	9.7263	0.3851	0.972
	60.0	0.12—0.81	8.3220	0.3921	0.985
Corn (Gustafson) 1973	10.0	0.13—0.96	13.6530	0.3054	0.998
	32.2	0.12—0.90	11.5178	0.3500	0.999
	48.9	0.12—0.85	10.3547	0.3851	0.993
	68.3	0.11—0.79	9.1879	0.3990	0.994
Popcorn (Flood) 1984	10.1	0.36—0.91	13.1895	0.3631	0.999
	20.1	0.19—0.91	12.2794	0.3695	0.996
	30.1	0.24—0.92	11.2185	0.3903	0.996
	39.8	0.29—0.93	10.3723	0.4111	0.996
	50.0	0.33—0.93	9.6044	0.4231	0.990
Peanut (Kososki) 1973	10.0	0.30—0.90	7.4851	0.3345	0.949
	15.0	0.30—0.90	6.7700	0.3643	0.965
	20.0	0.30—0.90	6.4268	0.3542	0.975
	25.0	0.30—0.90	6.1371	0.3500	0.990
	30.0	0.30—0.90	5.8249	0.3424	0.994
	38.0	0.30—0.90	5.4803	0.3605	0.991
Rapeseed Candle (Pixton) 1981	5.0	0.42—0.92	7.0346	0.4549	0.991
	15.0	0.22—0.92	7.0277	0.4418	0.993
	25.0	0.24—0.92	6.7326	0.4530	0.993
	35.0	0.27—0.92	6.3473	0.4742	0.994
Rice (Putranon) 1979	10.0	0.15—0.95	13.6300	0.2703	0.966
	20.0	0.23—0.93	12.9937	0.2791	0.979
	25.0	0.27—0.93	12.8192	0.2761	0.993
	30.0	0.22—0.77	12.5653	0.3565	0.991
	38.0	0.25—0.78	11.7872	0.3596	0.991
Rice (Zuritz) 1979	10.0	0.11—0.82	14.3754	0.2783	0.997
	20.0	0.11—0.87	13.2929	0.2973	0.992
	25.0	0.11—0.87	12.6575	0.3186	0.993
	30.0	0.11—0.86	12.0276	0.3189	0.982
	38.0	0.11—0.86	10.6320	0.3389	0.992
Sorghum (Dunstan) 1972	15.6	0.02—0.90	15.5266	0.2320	0.986
	23.9	10.02—0.89	14.5651	0.2637	0.997
	26.7	0.05—0.89	14.4220	0.2643	0.997
	40.6	0.05—0.89	13.4394	0.2818	0.997
	48.9	0.05—0.67	13.5288	0.3113	0.996
Soybean (Alam) 1972	5.0	0.14—0.89	10.8123	0.3942	0.967
	15.0	0.13—0.88	10.2087	0.4177	0.978
	25.0	0.12—0.87	9.9002	0.4361	0.976
	35.0	0.12—0.84	9.1659	0.4396	0.976
	45.0	0.12—0.85	8.3700	0.4859	0.988
	55.0	0.11—0.77	7.6494	0.5230	0.983
Wheat (Pixton) 1981	5.0	0.25—0.95	12.8138	0.3175	0.998
	15.0	0.27—0.95	12.3041	0.3290	0.999
	25.0	0.30—0.95	11.7014	0.4003	0.999
Gari (Ajibola) 1986b	40.0	0.12—0.82	10.1815	0.3500	0.979
	50.0	0.11—0.80	9.0613	0.3994	0.959
	60.0	0.11—0.80	8.3101	0.4003	0.973
	70.0	0.11—0.80	7.5892	0.3848	0.973

In this study, the main interest was to find the relation between parameters and temperature. Two type of function were selected:

a. Linear function:

$$K=a1+b1*T \quad (12)$$

$$N=d1+e1*T \quad (13)$$

b. Exponential function:

$$K=Exp(a2+b2*T) \quad (14)$$

$$N=Exp(d2+e2*T) \quad (15)$$

From a statistical analysis that compared the residual sum of the squares, the exponential function was not better than the linear function for describing K and N. The linear regression equation for the two parameters as a function of temperature are shown in Table 2. The result of an F−test indicated that the K parameters had a linear relation with temperature. While N did not exhibit a linear relation except for a few grains.

Table 2. The regression equation of K and N

Probuct	Regression Equation	R-square
Red beans	K=17.4705−0.182143*T N=0.1932+6.1557E−3*T	0.850 0.940
Winged beans	K=12.7003−9.9615E−3*T N=0.2801+3.8884E−3*T	0.958 0.900
Corn (Rodriguez−)	K=14.6985−0.10537*T N=0.2824+0.0165*T	0.989 0.609
Corn (Gustafson)	K=14.2209−7.6350E−2*T N=0.29397+1.6537E−3*T	0.986 0.961
Popcorn	K=14.0721−9.12375E−2*T N=0.34260+1.62528E−2*T	0.997 0.976
Peanut	K=7.92399−6.82593E−2*T N=0.34305+3.444E−4*T	0.951 0.100
Rapeseed	K=7.25690−0.02357*T N=0.4447+6.010E−4*T	0.881 0.333
Rice (Putranon)	K=14.3043−6.28147E−2*T N=0.21816+3.6614E−3*T	0.972 0.717
Rice (Zuritz)	K=15.7210−0.12495*T N=0.25956+2.03469E−3*T	0.996 0.961
Soyghum	K=15.1756−6.03475E−2*T N=0.20539+2.09464E−3*T	0.890 0.940
Soybean	K=11.24233−6.3043E−2*T N=0.3780+2.49234E−3*T	0.985 0.986
Wheat (Pixton)	K=13.1074−5.56187E−2*T N=0.31043+1.30992E−3*T	0.998 0.995
Gari	K=13.4760−8.5281E−2*T N=0.32174+1.05284E−3*T	0.988 0.335

With the above discussion a new Modified-Oswin equation was proposed that included the temperature term in the original Oswin equation, that is, K had a linear relation with temperature and N remained a constant.

The new modified nonlinear equation with three parameteres can be expressed as:

$$M=(A+B^{*}T)*(\frac{RH}{1-RH})^{N} \quad (16)$$

The ERH value can be written as a function of M and T,

$$RH=\frac{1}{(\frac{A+B^{*}T}{M})^{c}+1} \quad (17)$$

$$C=1/N \quad (18)$$

Mathematically, N reflects the sigmoid shape of the isotherm. A influences the magnitude of the ordinate at the temperature 0°C. B induces the temperature shift of the isotherm curve at a particular temperature, T.

A Fortran M77 program "NONLIN" which used the least squares method was written to estimate the parameters of the Modified-Oswin equation. The estimated parameters and the standard error of estimate of ERH (%) for several grains are shown in Table 3.

Table 3. Estimated parameters and S. E. of the Modified-Oswin equation for cereal grains

Product	Paramerers			S.E. of ERH
	A	B*(−100)	C	
Red beans	14.9607	8.2605	2.5183	3.2814
Winged beans	12.6259	9.9932	1.9106	4.7381
Corn (Rodriguez−)	14.6457	9.8022	2.9795	2.5332
Corn (Gustafson)	14.4014	8.4519	2.7545	2.7521
Popcorn	13.8135	8.2312	2.6189	1.0722
Peanut	7.7101	6.2351	2.9978	3.7386
Rapeseed	6.6909	1.8020	2.0773	0.8318
Rice (Putranon)	14.6362	7.2849	3.0930	2.7477
Rice (Zuritz)	15.6744	11.3673	3.3249	2.0342
Sorgrum	16.5271	6.7562	3.7721	1.9014
Soybean	10.9124	6.1544	2.1537	3.5133
Wheat	13.1009	5.2626	2.9987	0.8144
Gari	13.5656	8.6183	2.7891	3.6303

Calculated and experimented isotherm data for corn, popcorn, and soybeans at various temperatures are plotted in Fig. 1, 2, and 3. Values of S.E. (standard error for estimated value) and P (mean relative percentage deviation, different from the p value commonly used in statistical analysis) were calculated for purposes of comparing, the Modified-Henderson, the Chung-Pfost, and the Modified-Oswin equations (Table 4). Among these equations, the Modified-Oswin equation provided the best model for four grains.

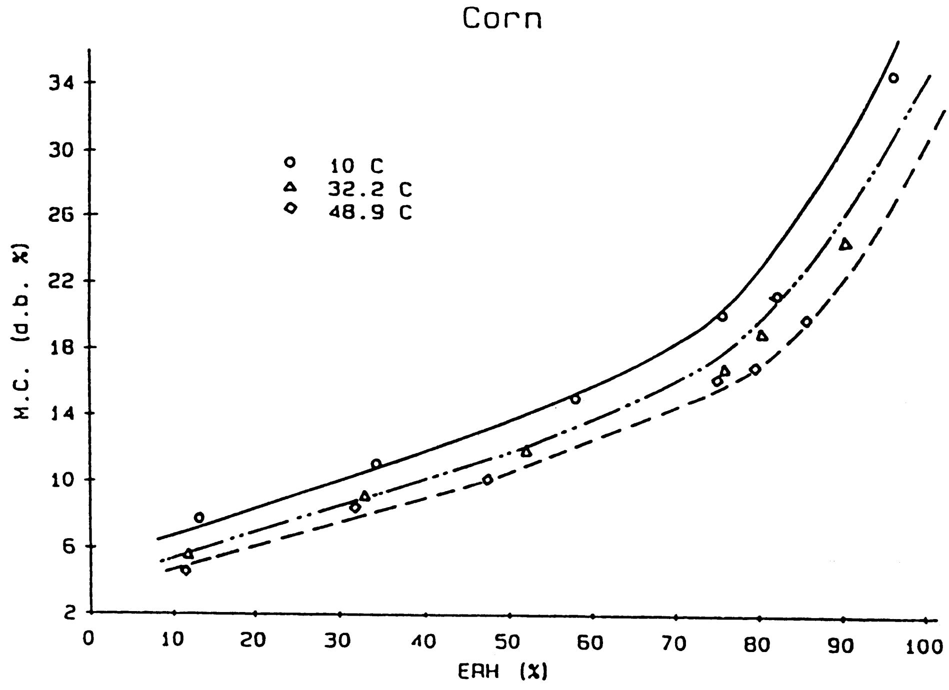

Fig. 1. Modified-Oswin equation and experimental data of Corn

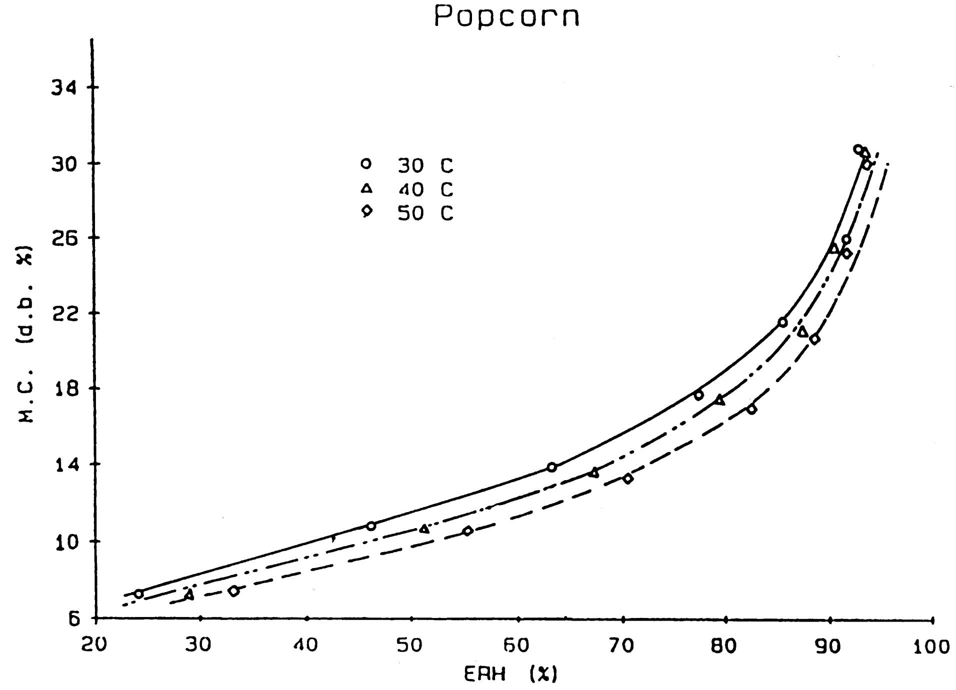

Fig. 2. Modified-Oswin equation and experimental data of Popcorn

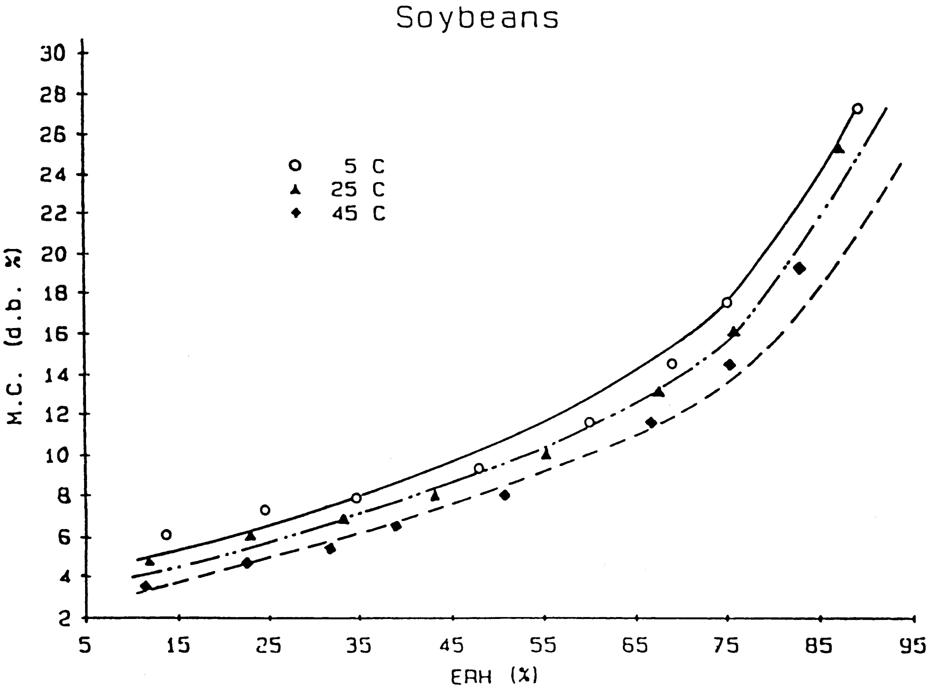

Fig. 3. Modified-Oswin equation and experimental data of soybeans

Table 4. Comparison of ERH equations for agricultural products

Product		Modified-Henderson	Chung-Pfost	Modified-Oswin
Red beans	S.E. P	4.1231 12.987	3.7464 11.519	3.2814 10.025
Corn (Gustafson)	S.E. P	3.7230 9.0137	2.8585 6.3065	2.7521 6.5762
Popcorn	S.E. P	2.9810 4.6250	2.5180 3.5820	1.0720 1.4870
Soybeans	S.E. P	5.0188 14.614	4.9923 14.335	3.5133 9.9601

1. S.E. : Standard error for relative humidity (%)
2. P : Mean relative percentage deviation

CONCLUSION

The Modified-Oswin equation,

$$M=(A+B^*T)^*(\frac{RH}{1-RH})^N$$

could be used to predicted well for the effect of temperature on sorption isotherms for some biological materials. Apparaently, the proposed equation is not accurate for all ranges of ERH(0.01—0.99) and cannot be claimed as the best "fitting-agreement" equation for all biologicial materials. However, it is a simpler form than the three-parameter equations that are often used. It describes the isotherm curve adequately for some cereal grains. Its parameters are determined by temperature and characterstics of the products.

Since the equation was derived empirically, no conclusion can be drawn from it to explain the mechanism of water sorption phenomena. Its simplicity, however, should be valuable for those who are more concerned with engineering applications of ERH models.

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歐思文平衡含水率模式之修正[1]

陳 加 忠[2]

摘 要

在此研究中提出一修正的歐思文模式以表示溫度對於數種農產品平衡含水率曲線的影響。各去濕方程式之參數列舉於此文中。此種含三參數的非線性模式能良好地適用於各實驗數據。即代表此模式能以簡單的形式描述農產品平衡含水率，平衡相對濕度和溫度三者之關係。

關鍵詞：修正歐思文模式，等溫曲線。

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1. 臺灣省農業試驗所 研究報告 1542 號。
2. 臺灣省農業試驗所農機系副研究員。臺灣省 臺中縣 霧峰鄉。

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The Study on the Application Equation for the Vaporization Heat of Water in Agricultural Products[1]

Chia-chung Chen Chien-chou Lai[2]

Abstract: The heat of vaporization of water in agricultural products is an important factor to design the drying equipment. The thermal properties can be calculated by an equation that derived easily form ERH/EMC equation by the Clausius-Claperton thermodynamic theory. The modified-Oswin equation can serve as the good model to obtain the heat of vaporization of corn kernel, rough rice and soybeans. The empirical model derived from the Othmer method gives the larger deviation.

Key words: Heat of vaporization, ERH model, Modified-Oswin equation.

INTRODUCTION

Drying processing is required for many agricultural products to maintain the good quality. Therefore, the vaporization heat of water (also be called latent heat of vaporization, heat of desorption, desorption-vaporization, notes as Q values) in agricultural products is of practical interest in drying operation. The value of vaporization is neither constant nor equal to the heat of evaporization of pure water. It is a function of temperature and moisture content, that is, the value is varied throughout drying processing. A simple model including moisture content and temperature term is very useful to compute the vaporization heat. This mathematical model also provide a good qualititative standard on the simulation work.

The purpose of this study is: (a) to review the methods of computing heat of vaporization that already reported in literature: (b) to compare the effect of ERH/EMC model on the properties: (c) to compare the computed values by different method.

LITERATURE REVIEW

The methods to compute the heat of vaporization for agricultural products are reported as following:

A. The direct calorimetric measurement

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1. Contribution No. 1543 from Taiwan Agricultural Research Institute.
2. Associate Researcher, Assistant Researcher, Agricultural Machinery Department, TARI, Wu-feng, Taichung, Taiwan, ROC.

This technique measured the heat of vaporization directly and have the higher degree of accuracy when determined with careful. However, the technique needs to measure small quantities of heat evolvod precisely. By this reason, calorimetrical measured heat of sorption are much less common than those computed from sorption data. This measurement mostly only be adopted on isolated food components (Bettelheim, 1970).

B. The calculation by BET equation

According the BET theory that proposed by Brunnauer, Emmett, and Teller(1938), the BET model includes two important parameters in food drying and storage.

In this model

$$\frac{Aw}{(1-Aw)}=\frac{1}{CMo}+\frac{(C-1)Aw}{CMo} \quad \cdots\cdots (1)$$

Where

Aw : Water activity of food

M : Equilibrium moisture content

Mo : Monolayer value

C : BET costant

and

$$C : Exp(Ef-Ec)/RT_a \quad \cdots\cdots (2)$$

Ta : Temp. °k

R the is gas constant, Ef and Ec are the heat of sorption in the first layer and the heat of condensation of the adsorbate. The difference between Ef and Ec are assumed as the heat of vaporization. After cheacking thirty-five cases, Iglesias and Chirife (1976) found that the BET heats are much lower than the values obtained by the Clausius-Clayperton heats (introducing in follow section). The same results are found by Aguerce and Viollaz (1983) on the study of the desorption heat of rough rice. The BET model is only valid in the lower RH range, so the BET heats are not considered in this study.

C. The Othmer equation

The relationship between Ps (saturated water vapor pressure) and the Pv (vapor pressure of water in agricultural product) was given by Othmer (1940) as :

$$In\ Pv=Q*InPs/X+constant \quad \cdots\cdots (3)$$

Where X : the heat of evaporization for pure water

Q : the heat of evaporization of agricultural product

This model assumed the Q/X value was independent of temperature.

From the linear regression analysis technique, the slope, Q, can be found from ln (pv) and ln (Ps) data. The relationship of Q and temperature, moisture content then be found by another regression technique. This method has been adopted by many researchers. Wang (1978) proposed the form of Q (heat of vaporization) for rough rice.

$$Q=(a-b*T)*M^c \quad \cdots\cdots (4)$$

T : Temp. °C

Thompson and Shedd (1954) presented an equation for the Q value of shelled corn by this least square procedure fron EMC data.

Their model was:

$Q=(1094-0.57*T)(1+4.35*Exp(-0.2825*M))$ ……(7)

The Unit of Q is KJ/kg.

Brook and Foster (1979) developed an equation for the Q value of rough rice:

$Q=2.32*[1094-1.026*(T_f+17.78)]*[1+2.4962*Exp(-0.2173*M)]$

T_f=Temp. °F ……(8)

The unit of Q is Btu/lb.

Fon (1988) mention an Islam–Jindal model to calculate the Q value of rough rice.

$L=a*(597.3-0.559*T)$ ……(9)

$a=1.315-0.0156*M+6.81E-5*M^2+3.836E-6*M^3$ ……(10)

The units of L is Kcal/kg.

D. The Clausius-Clapeyron equation

There are two methods to calculate the heat of evaporation by the Clausius-clapeyron thermodynamic model.

(a) Graphical method

From the Clausiusus-Claperton equation

$$\frac{\partial \text{InPv}}{\partial(1/Ta)}=-\frac{Q}{R} \quad \text{……(11)}$$

Where Pv : Partial pressure of water in agricultural product

Ta : Absolute temperature, K

R : Gas constant (0.4614 KJ/kg, K)

Q : Heat of vaporization, KJ/kg

By plotting lnPv (or ln Aw) vs. 1/Ta for a given constant grain average moisture content, Q could be computed from the slope of the curve.

(b) Integrated method

Integrating equation (11) for two isotherm temperatures, a new form of Q value is:

$$Q=R\left(\frac{Ta1*Ta2}{Tal-Ta2}\right)*\text{In}\left(\frac{Aw2}{Awl}\right) \quad \text{……(12)}$$

This method had to know two sets of isotherm data. Two temperature must closed enough so that the Q value could be applied for both isotherms.

Both method calculated the Q value at a specific moisture content. As the EMC/ERH relationships were estiablished by ERH determination, that is, the Aw data was measured at the constant moisture content, the error existed only in the experimental error. However, if the data sets of isotherm were obtained by tradictional EMC method, researchers need to plot the fitting curve from the scattering data and interporated the data from the plotting curve at the fixed moisture content. The errors of this method included the experimental error in the isotherm data and the graphical manipulation. The estimated error inherent in the process of plotting, curve drawing and interpolation was about 3.5% (Iglesias and Chirife, 1976). This technique is also a time-consuming operation.

E. Deriving from ERH model

The famous Clausius-Claperon thermodynamic model was :

$$\frac{\partial Pv}{\partial Ta}=\frac{Q}{Ta\triangle V}=\frac{Q}{Ta(Vg-Ve)} \quad \cdots\cdots (13)$$

Vg is the volume of gas, Ve is the volume of liquid. Vg is so large that Ve value can be neglected for (Vg−Ve) value.

$$\frac{\partial Pv}{\partial Ta}=\frac{Q}{Ta*Vg} \quad \cdots\cdots (14)$$

From the law of ideal gas, Vg=R∗Ta/Pv, equation (14) can be writter as :

$$\frac{\partial Pv}{\partial Ta}=\frac{QPv}{R*Ta^2} \quad \cdots\cdots (15)$$

$$\frac{\partial Pv}{Pv\partial Ta}=\frac{\partial In(Pv)}{\partial Ta}=\frac{Q}{R*Ta^2} \quad \cdots\cdots (16)$$

By the definition of Aw,

Pv=Aw∗Ps, substituting Pv value into equation(16)

$$Q=R*Ta^2*(\frac{\partial In(Aw)}{\partial Ta}+\frac{\partial In(Ps)}{\partial Ta}) \quad \cdots\cdots (17)$$

The second right-hand side term of equation is the heat of vaporization of pure water (X),

$$\text{so } X=R*Ta^2*\frac{\partial In(Ps)}{\partial Ta} \quad \cdots\cdots (18)$$

$$Q=R*Ta^2*\frac{\partial In(Aw)}{\partial Ta}+X \quad \cdots\cdots (19)$$

The similar results can be found for Zuritz and Singh (1985), Balaban et al. (1987), and Murata et al. (1988).

An Aw model can be substituted into equation (19) to obtain the Q value at different moisture content and temperature. Zuritz and Singh (1985) used this technique to find the Q value of rough rice. Three ERH models are adopted. The Day and Nelson equation, Chen-Clayton equation, and their new modified Henderson equation.

Balaban et al. (1987) estimated the heat of evaporation of some foods by same method. Four ERH/EMC models are selected to represent the relationhship among EMC, ERH and temperature. Murata et al. (1988) used the same method to calculate the thermal properties of five grains. They selected the Chen-Clayton equation as the best ERH/EMC model. However, the effect of inadequate model on the properties did not be metioned by researchers.

Hunter (1989) derived a similar equation with differental approuch to calculate the heat of sorption of Australian paddy rice.

From the ASHRAE handbook, Ps is the function of temperature,

$$Ps=Exp(54.63-6877/T-5.31*lnT) \quad \cdots\cdots (20)$$

T=Temp. °C

The Q values of pure water (X) is :

$$X=R*(6887-5.31*T) \quad \cdots\cdots (21)$$

Four ERH/EMC models incoperating temperature terms have been evaluated for sorption data of many agricultural products (Chen, 1988). These equations are adopted in this study to compute the Q value.

A. The Modified-Henderson equation

$$Aw=1-Exp(-A(T+C)*M^{b}) \quad \cdots (22)$$

Where Aw : water activity or ERH value (decimal)

M : m.c. in dry basis (%)

T : Temperature (°C)

A, b and C are constant.

Introducing equation (22) into equation (19),

$$Q=R*Ta^{2}*\frac{A*M^{b}*Exp[-A(T+C)*M^{b}]}{1-Exp[-A(T+C)M^{b}]}+X \quad \cdots (23)$$

B. The Chung-Pfost equation

$$Aw=Exp\left[-\frac{A}{T+C}Exp(-BM)\right] \quad \cdots (24)$$

$$Q=R\cdot Ta^{2}\left[\frac{A}{(T+C)^{2}}Exp(-BM)\right]+X \quad \cdots (25)$$

C. The Modified-Halsey equation

$$Aw=Exp(-Exp[A+B*T]*M^{-c}) \quad \cdots (26)$$

$$Q=Aw*Exp[A+B*T]*M^{-c}*B+X \quad \cdots (27)$$

D. The Modified-Oswin equation

$$Aw=\frac{1}{\left(\frac{A+B\cdot T}{M}\right)^{c}+1} \quad \cdots (28)$$

$$Q=\frac{\frac{-RT^{2}B*C}{M}\left[\frac{A+B*T}{M}\right]^{c-1}}{\left(\frac{A+B*T}{M}\right)^{c}+1}+X \quad \cdots (29)$$

The heat of vaporization calculted from equation (23), (25), (27), and (29) are compared with these computed from equation (12) to check the effect of fitting-agreement of ERH models on Q values.

MATERIALS AND METHODS

Isotherm data used in this study were introduced as following :

1. Rough rice (Tainun No. 67): Determined by Chen, Chou, and Tsao (1990) with hygrometric method.
2. Rough rice (U.S.A): Determined by Zuritz and Singh (1979) with gravimetric method.
3. Corn kernel : Determined by Chen (1988) with hygrometric method.
4. Corn cob : Determined by White et al. (1985) with hygrometric method.
5. Soybeans : Determined by Alam (1972) with gravimetric method.
6. Black tea : Determined by Yoshitomi (1985) with gravimetric method.
7. Oolong tea : Determined by Chen, Chou, and Tsao (1990) by hygrometric method.

8. Fench tea : Ddtermined by Wolf et al. (1973) with gravimetric method.

RESULTS AND DISCUSSIONS

To compare the effect of ERH model on heat of vaporization of corn kernel, the computed values from four ERH models and Thompson-Shedd equation are listed in Table 1 and showed in Figure 1. The Q values that calculated by equation (12) are scattered in Fig. 1. to check the fitting-agreement of the calculated values.

In Fig. 1, the Q values that computed from the Modified-Henderson equation and Modified-Oswin equation give the good fitting performance with scattering data. These values obtained from the Chung-Pfost equation were too low in the m.c. range of

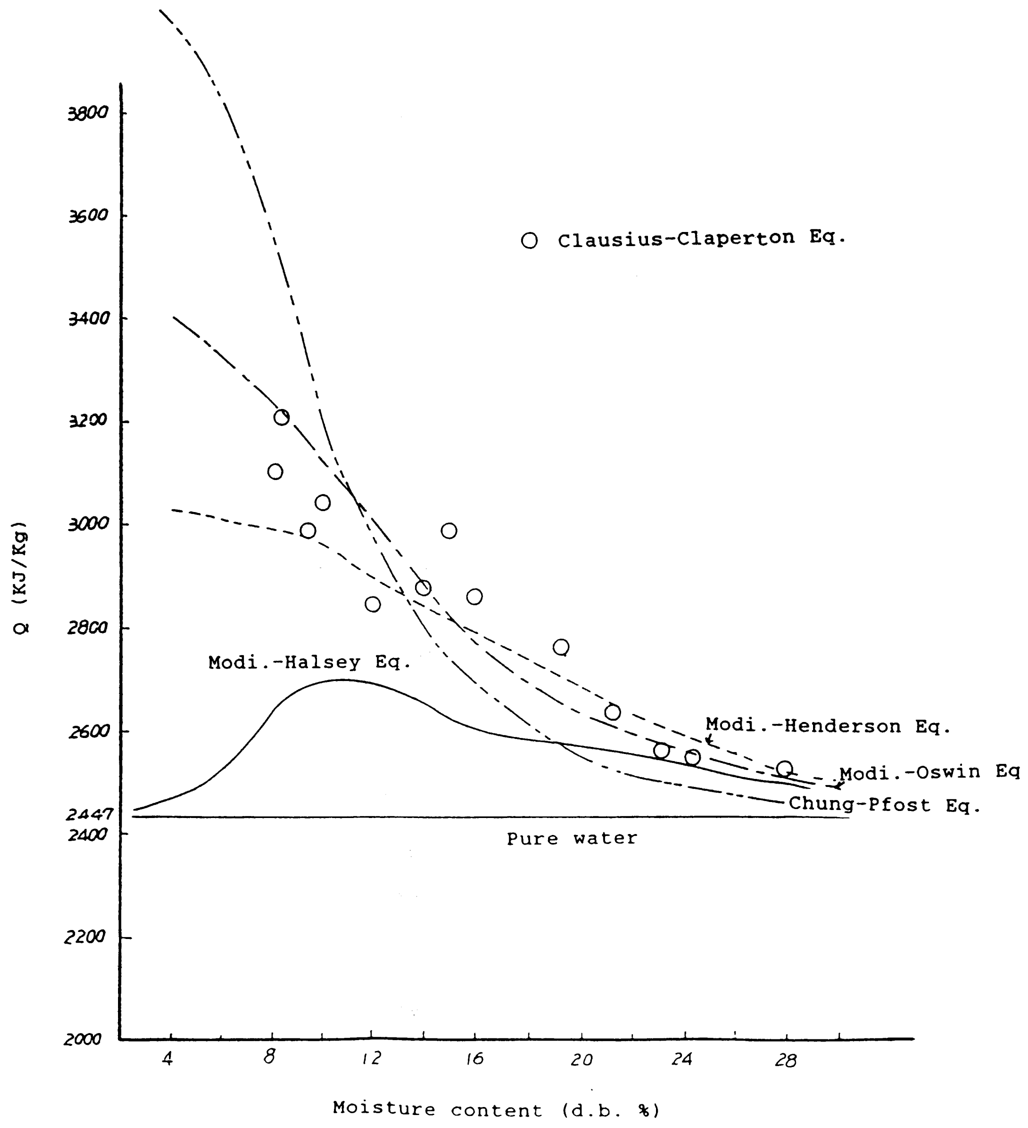

Figure 1. Heat of vaporization for corn kernel at 25°C

above 14% and too high below the m.c. range of 14%. The Q values obtained from the Modified-Halsey equation always lower than those calculated from equation (12). Chen (1988) had reported the Modified-Henderson and Modified-Oswin equation were the adequate models for the specific variety of corn kernel. This results suggested the important to use the adequate ERH model to calculated the Q values.

The Q values calculated from Thompson-Shedd equation were too high at low m.c. in Table 1.

Table 1. Q values computed with four ERH models for corn kernel

Temp (°C)	m.c. (%,d.b)	Modified -Henderson	Chung -Pfost	Modified -Oswin	Modified -Halsey	Thompson and Shedd
	4	3,235	7,200	3,228	2,496	5,990
	6	3,214	5,735	3,197	2,524	4,565
	10	3,148	4,031	3,086	2,698	3,192
5 X=2,496	16	3,009	2,998	2,825	2,684	2,658
	20	2,902	2,734	2,709	2,638	2,577
	26	2,747	2,573	2,610	2,588	2,545
	30	2,662	2,533	2,574	2,566	2,541
	4	3,037	4,711	3,412	2,449	5,928
	6	3,012	4,006	3,350	2,533	4,517
	10	2,940	3,186	3,120	2,700	3,159
25 X=2,447	16	2,793	2,688	2,779	2,627	2,630
	20	2,690	2,561	2,650	2,575	2,550
	26	2,564	2,484	2,550	2,527	2,519
	30	2,509	2,464	2,517	2,507	2,514
	4	2,910	3,807	3,681	2,413	5,865
	6	2,883	3,368	3,547	2,575	4,469
	10	2,802	2,858	3,142	2,678	3,126
45 X=2,398	16	2,650	2,548	2,706	2,561	2,062
	20	2,554	2,469	2,574	2,509	2,523
	26	2,455	2,421	2,483	2,465	2,492
	30	2,422	2,409	2,455	2,449	2,487

The Q value of rough rice calculated fron four ERH models are showed in Fig. 2. The curve of Q values obtained from the Modified-Oswin equation had the best fitting performance with the scattering data calculated from Eq. (12). Chen et al. (1990) found this ERH model is the only adequate model to represent the relationships among ERH, EMC, and temperature of rough rice. This results also indicated the effect of ERH model on the Q values.

Four sets of Q values of rough rice from difference or method are listed in Table 2. Some differences exist between the Q values from two sources (Zuritz et al., 1979 and Chen et al., 1990). Q values are affected by various factors.

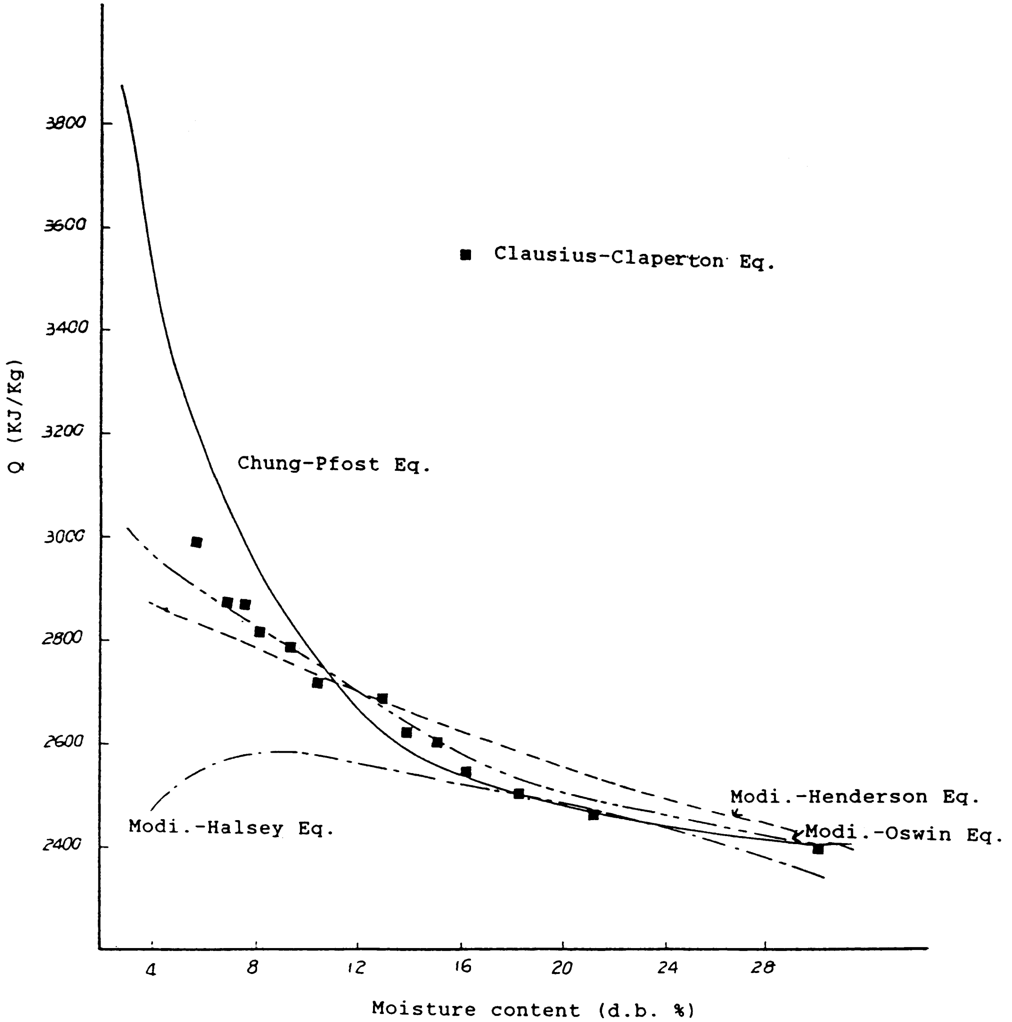

Figure 2. Heat of vaporization for rough rice at 25°C

Table 2. Comparing the computed Q value of rough rice at 25°C

m.c. (%,d.b)	data source Zuritz	Chen	Brook and Foster equation	Islam and Jindal
4	3,212	2,969	4,986	2,622
6	3,185	2,907	4,087	2,618
10	3,090	2,739	3,128	2,610
14	2,951	2,611	2,726	2,603
16	2,871	2,570	2,624	2,600
20	2,711	2,520	2,515	2,595
24	2,583	2,492	2,470	2,590
26	2,536	2,483	2,458	2,588
30	2,478	2,471	2,445	2,586

The Q values obtained from the Brook-Foster equation were too high at low m.c. range. The Islam-Jindal equation gave very low values. This results showed that the Qs model derived fron the Othmer method were inadequately.

The Q values of Soybeans from four ERH models and equation (12) are showed in Figure 3. Chen (1988) reported the Modified-Halsey equation and the Modified-Oswin equation can be accepted as the good models for ERH/EMC properties. However, the Q values calculated from the Modified-Halsey equation is too low. The results can be explained from the structure of the model. From the mathematic form of equation (26), it is meaningless for the moisture content as ERH apporaching zero, that is, the Modified-Halsey equation cannot describe the ERH/EMC properties at very low m.c. value or ERH value. The Modified-Oswin equation was the only adequate model to calculate the Q values of all RH range.

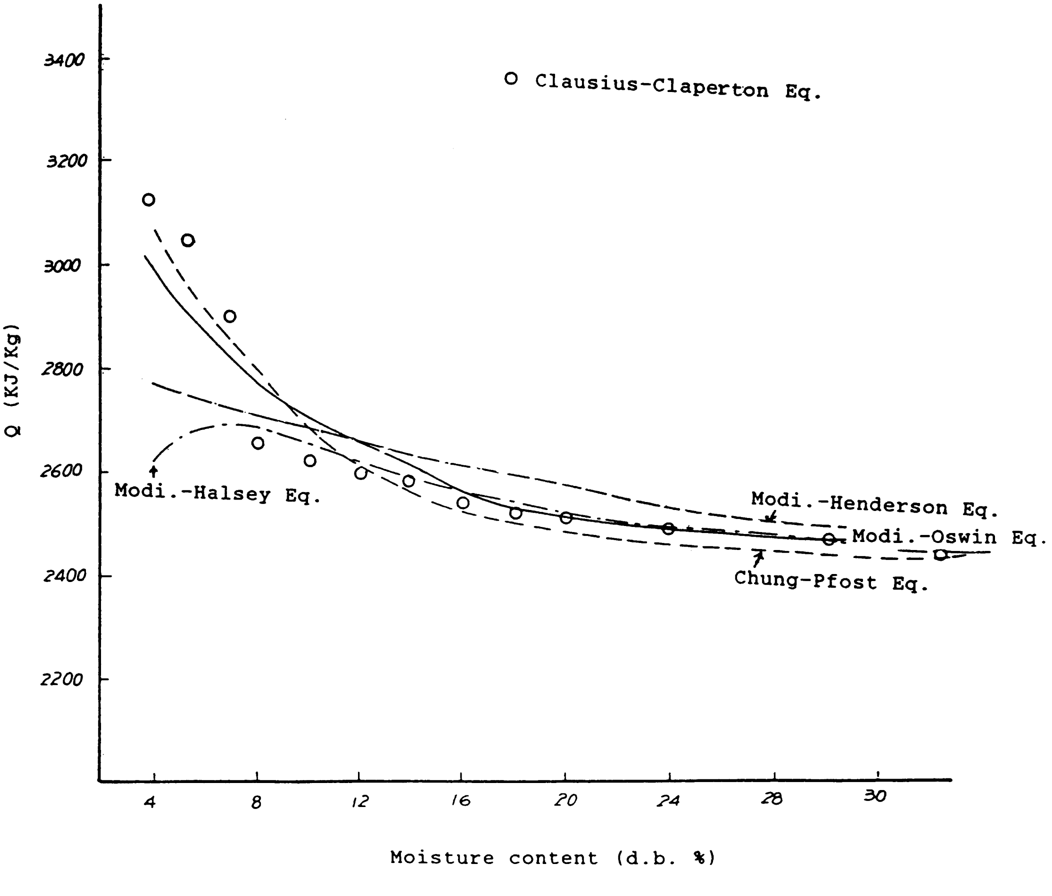

Figure 3. Heat of vaporization for soybeans at 25°C

The Q values for three tea products are showed in Figure 4. The Black tea had the highest heat of vaporization at the same moisture content. The results indicated the Q values were affected by different processing method or variety.

The comparison of Q values for five agricultural products are showed in Figure 5. The ranks of Q values are : Corn kernel > Rough rice > Corn cob > Soybeans > Tea. The heat of evaporization of starchy grains and fibrous is higher than those of high oil and protein products at the same moisture content.

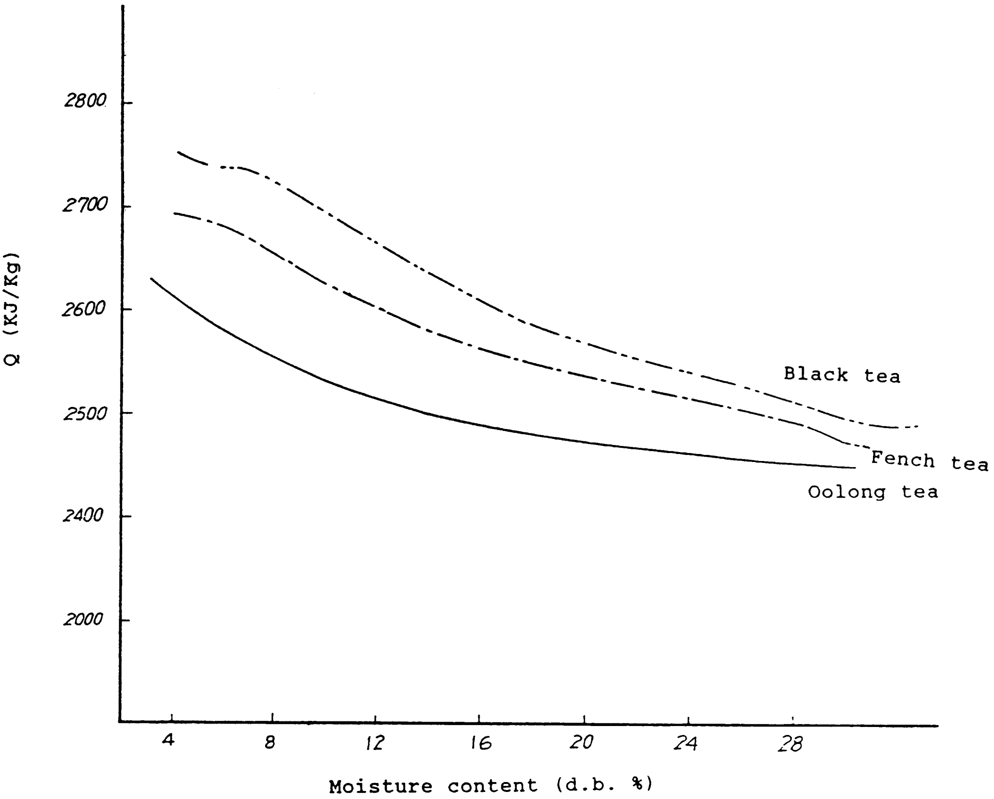

Figure 4. Heat of vaporization for tea at 25°C

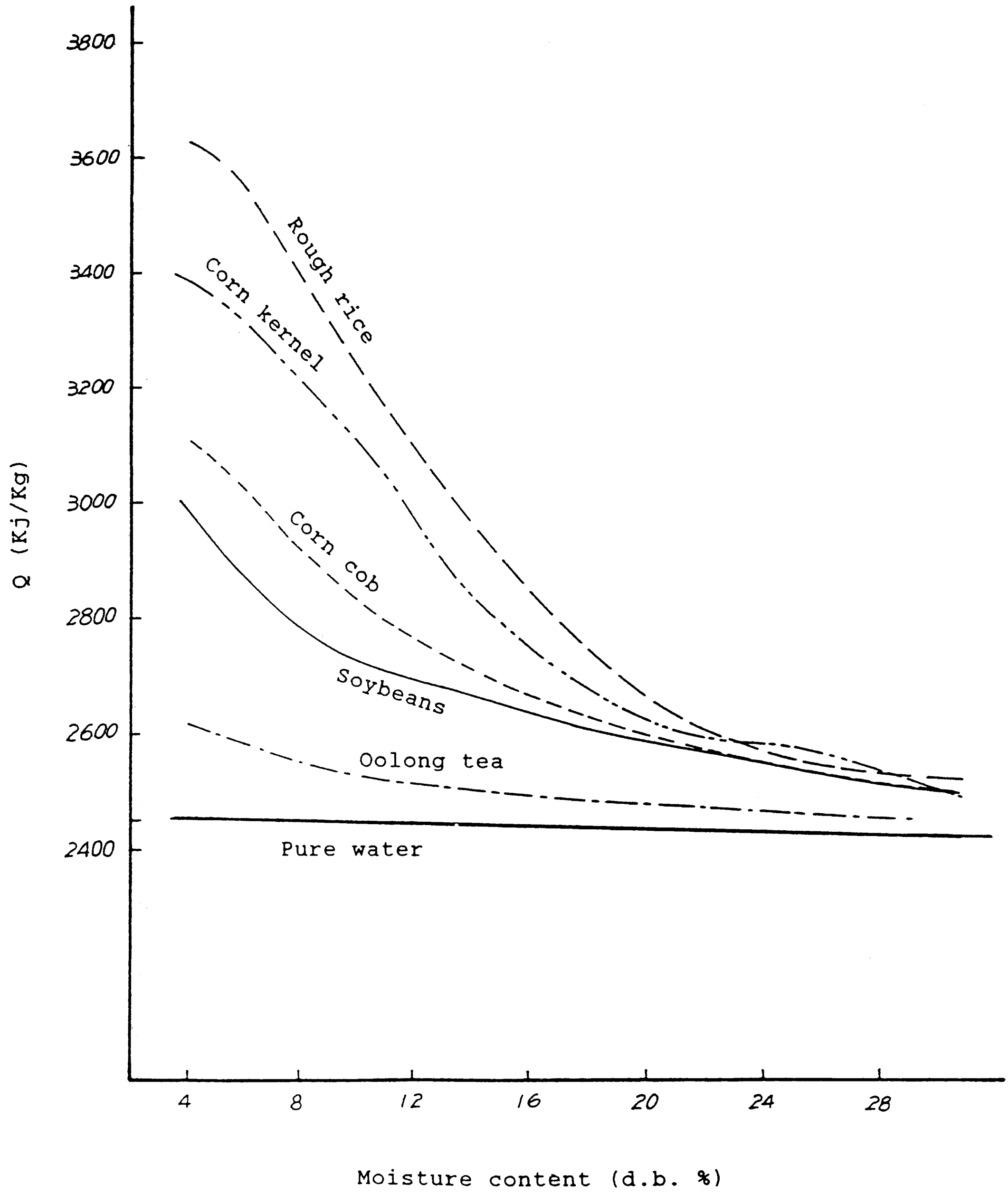

Figure 5. Heat of vaporization for five agricultural products at 25°C

CONCLUSIONS

1. An equation of heat of evaporation can be derived easily from the ERH/EMC model by the Clausius -Clapeyron theory.
2. The fitting performance of the ERH/EMC equation affects the values of heat of evaporization. The Modified-Oswin equation is the good model to evaluate the heat of evaporization of water in corn kernel, rough rice, and soybeans.
3. The empirial model obtained from the Othmer method did not give the satisfactory result.

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農產品水份蒸發熱之應用模式研究[1]

陳加忠　賴建洲[2]

摘　要

農產品內部水份蒸發熱物性在乾燥設備之設計上十分重要。在此研究中，由 Clausius-Claperton 熱力動力學原理可自平衡相對濕度模式推衍一簡易應用模式以計算此熱學物性。由修正歐思文模式推導所得的計算公式可應用於玉米粒，稻穀和大豆此項物性之計算。由 Othmer 方法所得的經驗公式存有極大的誤差。

關鍵詞：水份蒸發熱，平衡相對濕度模式，修正歐思文公式。

1. 臺灣省農業試驗所　研究報告第 1543 號。
2. 本所農機系副研究員、助理研究員。臺灣省　臺中縣　霧峰鄉。

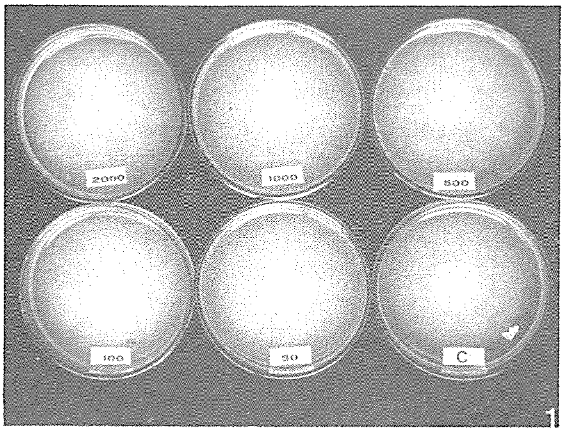

FIG.1. MYCELIAL GROWTH OF L. EDODES IN PDA MEDIUM CONTAIN VARIOUS CONCENTRATIONS (PPM) OF CULTURAL FILTRATE OF C. VERSICOLOR.

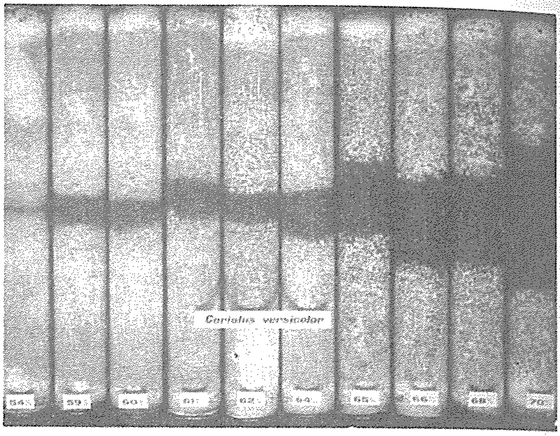

FIG.2. MYCELIAL GROWTH OF C. VERSICOLOR ON VARIOUS WATER CONTAINS OF SAWDUST MEDIUM.

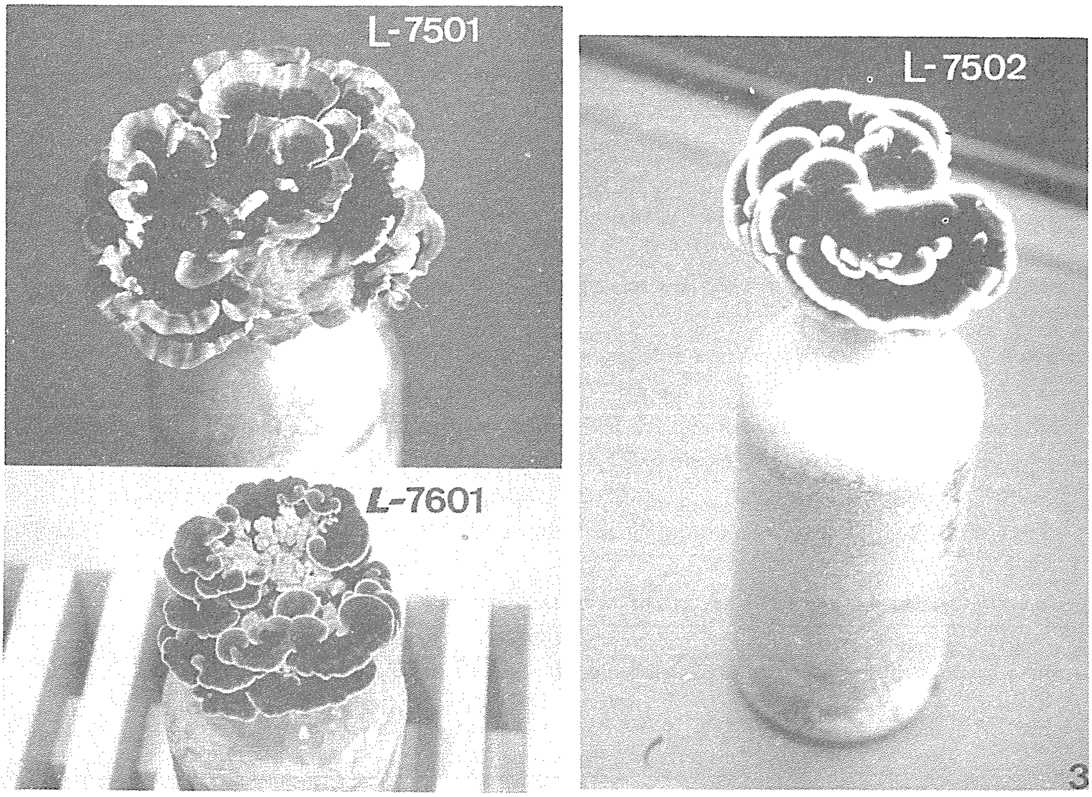

FIG.3. FRUITING BODIES OF THE THREE ISOLATES OF C. VERSICOLOR ON SAWDUST MEDIUM.

呈現一個條帶，其移動性相同。 GOT 則均爲三個條帶，且可分爲兩群，品種間沒有差異。 IDH 同樣也是具有兩個條帶，沒有差異。 MDH 在膠片的正極上均呈現三個條帶，而負極的酵素活性較低，不易判斷是二或三個條帶，但品種之間也沒有差異。另外，種子活力較低時，各 MDH 的同功異構酶活性較低，且會分解產生移動性不同的條帶，催芽後胚根沒有生長的種子則只有極弱的活性。

SkDH 及 PRX 在供試品種間具有差異，該兩種酵素的分析情形敍述如下：

1. Shikimate dehydrogenase (SkDH)

甜瓜幼苗子葉或催芽種子內含的 SkDH 主要有兩型，一個是 Rf=0.47 的條帶，一個是 Rf=0.50 的條帶（圖1），Rf 0.47 型的前端尙有三條次要的條帶（Rf 分別爲 0.49，0.51，0.53），後端（Rf<0.47）另有一條次要條帶，這些條帶在有些個體較强，有些個體較弱。Rf 0.5 型的也有一條次要條帶（Rf=0.51），也是在有些個體强，有些個體弱。Rf 0.47 型的品種有 PMR 及西施，而 Rf 0.5 型的品種有黃金及新玉(圖1)。Rf 0.47×Rf 0.5 的後代呈混合型，其 F_1 均具有 Rf 0.47 及 Rf 0.5 條帶（圖1），偶而也有次要條帶出現於 F_1，但不影響結果之分析，以 PMR，新玉及其 F_1, F_2 再分析一次時，可見到 PMR 的次要條帶（圖2箭頭所指）很明顯，但在 PMR×新玉的 F_1 個體就很淡，而在其 F_2 代樣品中可見兩個主要條帶會分離，由於不同批電泳結果，其 Rf 值稍有變化，因此將圖1中 Rf 0.5 條帶暫時命名爲 SkDH-F，而 Rf 0.47 條帶命名爲 SkDH-S，分

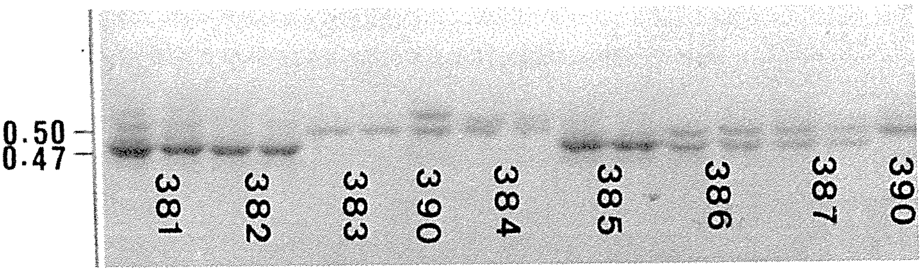

圖1. 甜瓜的 SkDH 酶型圖。主要的條帶爲 Rf 0.47 及 Rf 0.50. 前者命名爲 SkDH-S，後者命名爲 SkDH-F. 381=PMR, 382=西施，383=黃金，384=新玉，385=PMR ×西施，386=PMR×黃金，387=PMR×新玉，390=387F_2.

Fig. 1. Zymogram of melon SkDH isozymes. Major bands have Rf value of 0.47 and 0.50. The former is named as SkDH-S and the latter SkDH-F, respectively. 381=PMR, 382=Hsi-Shih, 383=Hwang-Jin, 384=Shin-Yuh, 385=PMR×Hsi-Shih, 386=PMR×Hwang-Jin, 387=PMR×Shin-Yuh, 390=387F_2.

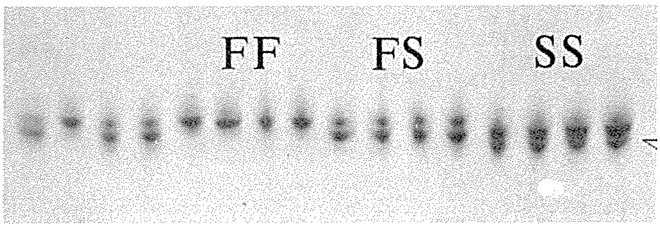

圖2. PMR，新玉兩個甜瓜品種及其 F_1, F_2 幼苗子葉中的 SkDH 同功異構酶。從圖右開始1—4行=PMR，5—8行=PRM×新玉，9—12行=新玉，13—16行=(PMR×新玉) F_2. 在本圖中，PMR 的 SkDH-SS 多了一條明顯的次要條帶（箭頭所指）。

Fig. 2. SkDH isozymes in seedling cotyledons of PMR, Hsin-Yuh, F_1 and F_2. Note an minor band (arrow) appeared in SkDH-SS of PMR. For right to left, lanes 1—4=PMR, 5—8=PMR×Hsin-Yuh, 9—12=Hsin-Yuh, 13—16=(PMR×Hsin-Yuh) F_2.

析52株 PMR×新玉的 F_2 結果爲（表現型）：11FF, 27FS, 14SS ，經卡方測驗分析，得 $x^2=0.42$ ，其值在 P=0.05 時小於3.84，顯示符合孟德爾一對基因的1：2：1之比，因此推斷供試材料的 SkDH 由一個基因座的兩個共顯性對偶基因（*Skdh-F* 及 *Skdh-S*）所控制。

2. Peroxidase (PRX)

催芽但尚未照光的種子所含的 PRX 活性較弱，且只有靠近膠體原點的部份才有條帶出現，這顯示 PRX 的表現受到發育階段的控制。若以幼苗的綠色子葉分析 PRX 時，近正極的位置可見到兩種不同移動性的三個條帶（圖3），PMR 品系的 PRX 爲移動性較慢的三條，而西施，黃金及新玉品系的 PRX 爲較快的三條，且兩群間有二條重疊（圖3），因此 PMR ×新玉呈現四條 PRX（圖4），而 F_2 則分離成三型，依據 Dane (1983) 的命名，供試材料的 PRX 表現型可命名爲 PRX-2A2A, 及 PRX-2B2B，其 F_1 爲 PRX-2A2B，而 F_2 則分離成 PRX-2A2A, PRX-2A2B 及 PRX-2B2B，因此暫時將其基因定爲 *Prx-2A* 及 *Prx-2B*，由分離情形可以推斷是由一個基因座兩個對偶基因所控制，PMR 品系的基因型屬於 *Prx-2B2B*，而其他三個品系的基因型則爲 *Prx-2A2A*.

若澱粉膠體以不同的緩衝液來分析，所得的結果也類似，但其解析力有差異，以 C 緩衝液（表1）分析 PRX 時，某些條帶的表現就比較不清楚（圖4），但其條帶分佈則和 A 系統的類似。

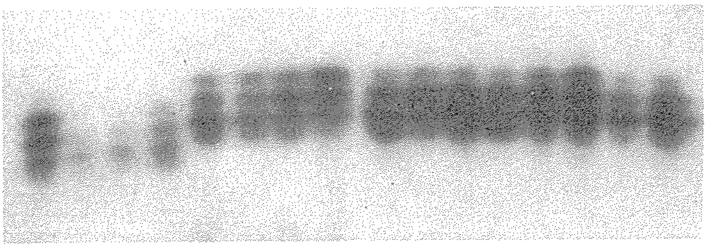

圖3. 四個甜瓜品種的 PRX-2 酶型圖。（由左至右）1—4行=PMR，5—8行=西施，9—12行=黃金，13—16行=新玉。

Fig. 3. Zymogram of PRX-2 in four melon varieties. From left to right, lanes 1—4=PMR, 5—8=Hsi-Shih, 9—12=Hwang-Jin, 13—18=Shin-Yuh.

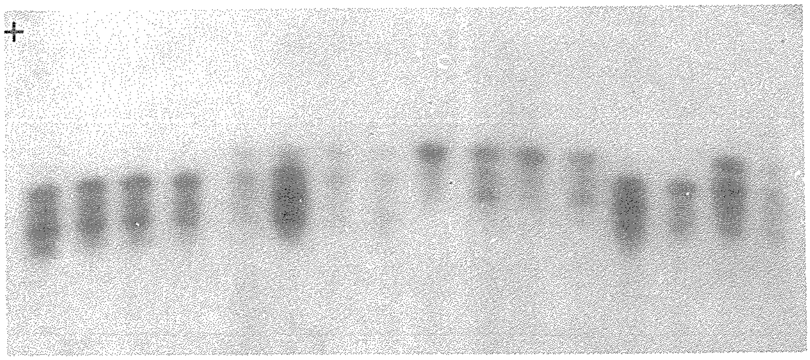

圖4. 甜瓜幼苗子葉的 PRX-2 在10%澱粉膠 A 緩衝液系統上的酶型圖。（由左至右）1—4行=PMR，5—8行=PMR ×新玉，9—12行=新玉，13—16行=（PMR ×新玉）之 F_2 代。圖中只顯示正極的條帶，其餘尚有分佈在原點和負極的條帶則未顯示出來。PMR 屬於 PRX-2B2B，新玉屬於 PRX-2A2A ，其 F_1 則爲 PRX-2A2B.

Fig. 4. Banding pattern of PRX-2 allozymes in cotyledons of young melon seedlings resolved in 10% starch gel with buffer A. Other isozyme bands near the origin and the cathode are not shown.

中 華 農 業 研 究

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